BBC

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Science Focus

THE MECHANISMS IN THE MIND THAT DEFINE YOU

HOW YOUNG BLOOD REJUVENATES AGEING BRAINS

WHY TECH DETOXES AREN'T A SIMPLE FIX FOR BURNOUT

ALIEN EARTHS

How finding life on other planets is becoming a reachable goal

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Why a supermassive black hole hasn't devoured us... yet

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Group workouts make you fitter

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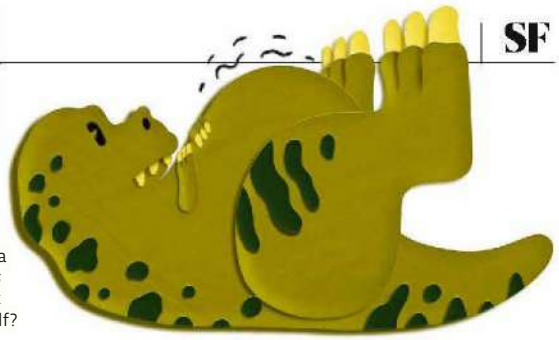
FROM THE EDITOR



How many people would a *Tyrannosaurus rex* have to eat to sustain itself? →p76

At the start of the year, the James Webb Space Telescope moved our horizons. It enabled us to see deeper into space and further back in time than ever before. Since then, Webb has provided new discoveries at an almost metronomic pace. It's shown us some of the earliest, complex molecules in space; uncovered more black holes than we thought there were; allowed us to examine the birth of stars in unprecedented detail and much more besides. Suffice to say, it's been a productive first year for Webb. So it might surprise you to learn that NASA is already working on its successor: the Habitable Worlds Observatory (HWO).

Why so soon? Well, the simple answer is that projects like these take decades to design, develop and build: one era-defining project, whether it be Webb or HWO, is nominated by NASA to pursue at the start of each decade. But I also like to think that it's because we're finally, properly pushing to answer to the biggest question in science: are we alone in the Universe? Or, more specifically, is Earth, and its ability to support life, unique?

To answer this question, the HWO will be equipped with sensors that scan a whole swath of the light spectrum, so it can determine what molecules are present in a distant planet's atmosphere. It will also be built with repair and servicing in mind, so that, unlike Webb, it can avoid lengthy delays during the construction process. Head to p56 to find out what we know about the project so far.

And if, like me, you're deeply curious about the search for extraterrestrial life, then I urge you to seek out our Instant Genius podcast. In September we're talking to Harvard Prof Avi Loeb, who's been searching for alien artefacts here on Earth. Enjoy the issue!

Daniel Bennett, Editor

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COVER: MAGIC TORCH THIS PAGE: WILL AMLOT, ALAMY, BBC ILLUSTRATION: HARRIET NOBEL

ON THE BBC THIS MONTH...

The Documentary: Inside an Autistic Mind
Science journalist Sue Nelson discovered she was autistic last year, aged 60. To help her understand her diagnosis, how it reframes her personal history, and what a diagnosis means for her future and for the millions of others with autism, Sue speaks to leading scientists, writers and artists about how life plays out when your brain works in a different way.
BBC World Service, 9 September 12pm (BST) Also available on BBC Sounds

The Gift
DNA kits that promise to reveal your ancestry have become popular presents. But what happens when what they reveal is something life-changing? This fascinating series explores the science and stories surrounding genealogy tech, exposing scandals, upending identities and solving mysteries in the process.
BBC Radio 4, 11 September 11am Also available on BBC Sounds

The Sky at Night: Is There Anybody out There?
As it happens, in *The Sky at Night*'s July episode, the team took a deeper look at what would happen if we discovered alien life. The show asks the question: how would we speak to extraterrestrial beings? And perhaps more pressingly, should we speak to them? Is there any reason to think a conversation with another intelligent species would end well?
Available now on BBC iPlayer

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Part of the Dept of Public Health and Primary Care at the University of Cambridge, Michael investigates the implications of lowering UK speed limits to 20mph. → p36

PROF ADAM HART
Entomologist Adam looks into whether insects could creep onto our plates via a potentially more palatable route: in the feed used to rear farm animals. →p48

DR DEAN BURNETT
Could other realities help you deal with your reality? Neuroscientist Dean explores the ways VR and psychedelics can treat mental health issues. →p66

HAYLEY BENNETT
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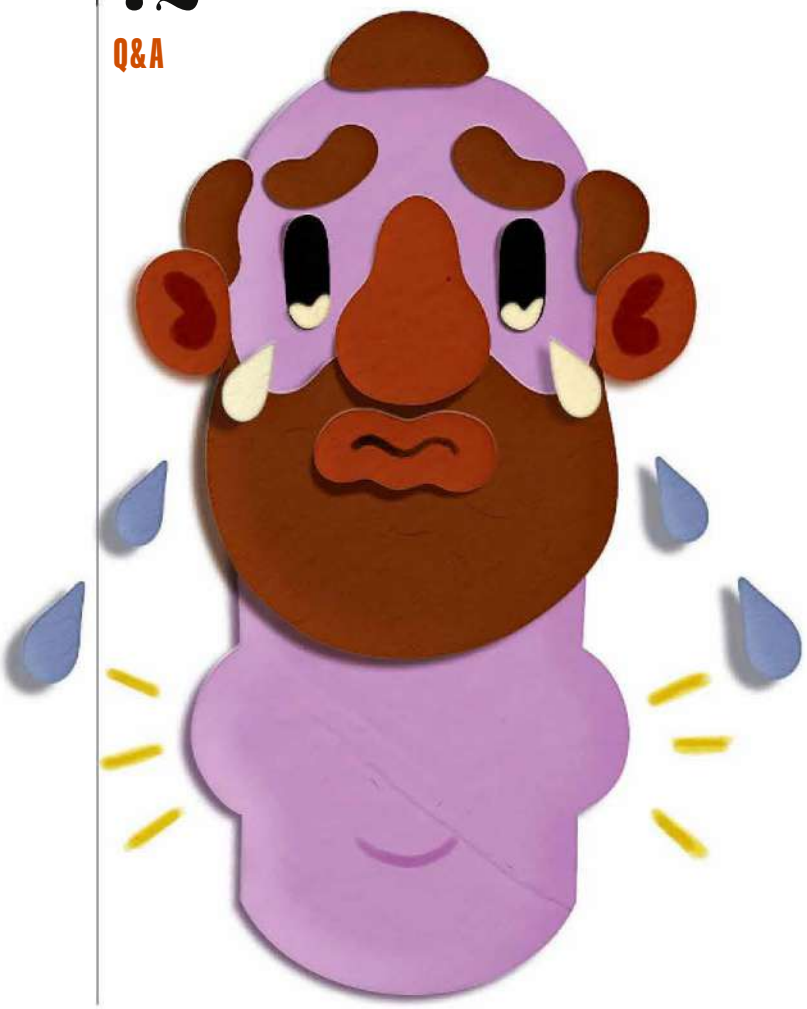

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EYE OPENER

Fire and water

BOCA CHICA, TEXAS

The word deluge typically describes a downpour, but this deluge goes upwards. The water you see here gushing up through the platform of the SpaceX facility in Texas is a demonstration of the system designed to protect the launch mount.

The deluge system is being installed because Starship, which stands 120m (394ft) tall and is the most powerful rocket ever built, produces a destructive amount of thrust. The first launch of a 'fully stacked' Starship in April ended in an explosion four minutes into its (crewless) flight. But before it self-destructed, Starship's 30 Raptor engines blasted a huge crater in the platform beneath its launch mount, causing rocks and debris to rain down on the surrounding area.

By blasting water upwards beneath the next Starship to take off, SpaceX hopes to protect the launch pad as well as dampen the noise generated by the reuseable rocket's launch.

SPACEX

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EYE OPENER

Feathering the nest

ANTWERP, BELGIUM

The magpie nest pictured here shocked scientists when it was discovered during tree maintenance operations in Antwerp, Belgium. It contains over 1,500 spikes stolen from the city's anti-bird defences.

The unlikely nest materials probably help magpies ward off other birds, according to Auke-Florian Hiemstra (also pictured here) of the Naturalis Biodiversity Center in the Netherlands, the biologist who has been documenting urban nests like this.

"From all the nests I know (and as a nest researcher I look at many, many nests) this is definitely the craziest nest I have ever seen," Hiemstra told *BBC Science Focus*. "Birds are using our bird-deterring materials to build nests and to make more birds. That's a perfect comeback."

Similar nests have been discovered in Rotterdam and Enschede in the Netherlands and in Glasgow. They were all built by corvids (the family of birds that includes crows and magpies) and include a range of materials from barbed wire to knitting needles.

"This is the charm of urban ecology – that you can make these discoveries in the middle of big cities," said Hiemstra.

ALEXANDER SCHIPPERS

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EYE OPENER

Tomatoes off the vine

WAGENINGEN,
NETHERLANDS

Who needs a window box – let alone an allotment – when you've got tomatoes that can grow without a plant?

These tomatoes were grown in a laboratory in Wageningen University, in the Netherlands, by Lucas Van der Zee. Lucas, a biologist, is conducting experiments to see if it's possible to produce crops without all the usual essentials, such as soil, sunlight and, in this case, roots. In other words, he's trying to grow fruit that don't need plants.

The immature tomatoes were harvested as soon as they were fertilised and put into the Petri dish-like plates. Not only did they continue growing, but some also began to develop stems and root structures.

The aim of this endeavour is to find new forms of food production that limit the environmental impacts associated with traditional agriculture. If successful, it might be a step on the way to producing tomatoes from the undifferentiated cells from which new plant organs grow, potentially eliminating the need for the plant entirely.

FRANCESCO RUCCI/FRANCESCO MARINELLI
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FEEDBACK

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND OUR MAGAZINE

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LETTER OF THE MONTH

Does bringing the thylacine back from extinction raise more questions than it answers?

Jurassic Park, but without the dinos

I have just had my third spinal surgery and had to deal with some mental health issues, but *BBC Science Focus* magazine and its podcasts have really helped my recovery. I listen to the podcasts during my daily walks and any other time I can squeeze one in.

The podcast episode about the project to bring the thylacine, or Tasmanian tiger, back from extinction got my mind racing. Besides the obvious positives around what this could do for conservation, what stops this from becoming a *Jurassic Park* scenario, where scientists fill in the genetic blanks with genes from the closest-living relative? And what could that mean for the new hybrid animal this creates?

But beyond those practical questions, who oversees the ethical issues regarding local and global ecology, and the animals themselves? If the project is successful, who gets to say whether the animals get a wild release, or if they and the whole project gets terminated?

Colin Bunyard, Sleaford

WRITE IN AND WIN!

The writer of next issue's *Letter of the Month* wins ***a trio of paperback science books***. Put pen to paper and you could get your hands on *An Intimate History of Evolution* by Alison Bashford; *Hothouse Earth* by Bill McGuire; and *Impossible, Possible and Improbable* by John Gribbin.

Young and old agree

I was very pleased to read William Rawlings letter regarding climate change (Summer, p11). He is 14 and I am 75, but I totally agree with him; we should focus on solving the problem of climate change on this planet, before we spend billions on going to explore others. Unfortunately, I think national economics will dictate what happens in the future. Hence, countries must work together and forget about their economies.

Paul Spraggins, via email

XX = XY

It's refreshing to see that so many of your contributors are professional women scientists instead of being a publication that's dominated by male writers. It's time for women to be given their rightful places among the ranks of intellectuals.

Paul WH Tung, via email

Unintended consequences

I read with interest Prof Stephon Alexander's column, 'Who's Afraid of the Big Bang Singularity?' (August, p28). While it's certainly true to say that the term 'Big Bang' was coined by the late Prof Fred Hoyle during a 1949 BBC broadcast, this was actually his term of derision for a theory to which he did not subscribe – and thereafter, ironically, it stuck to the theory. He and some eminent colleagues were and remained ardent supporters of the alternative 'steady state' theory. For more information, I recommend his book, *The Intelligent Universe*.

Irene Wears, via email

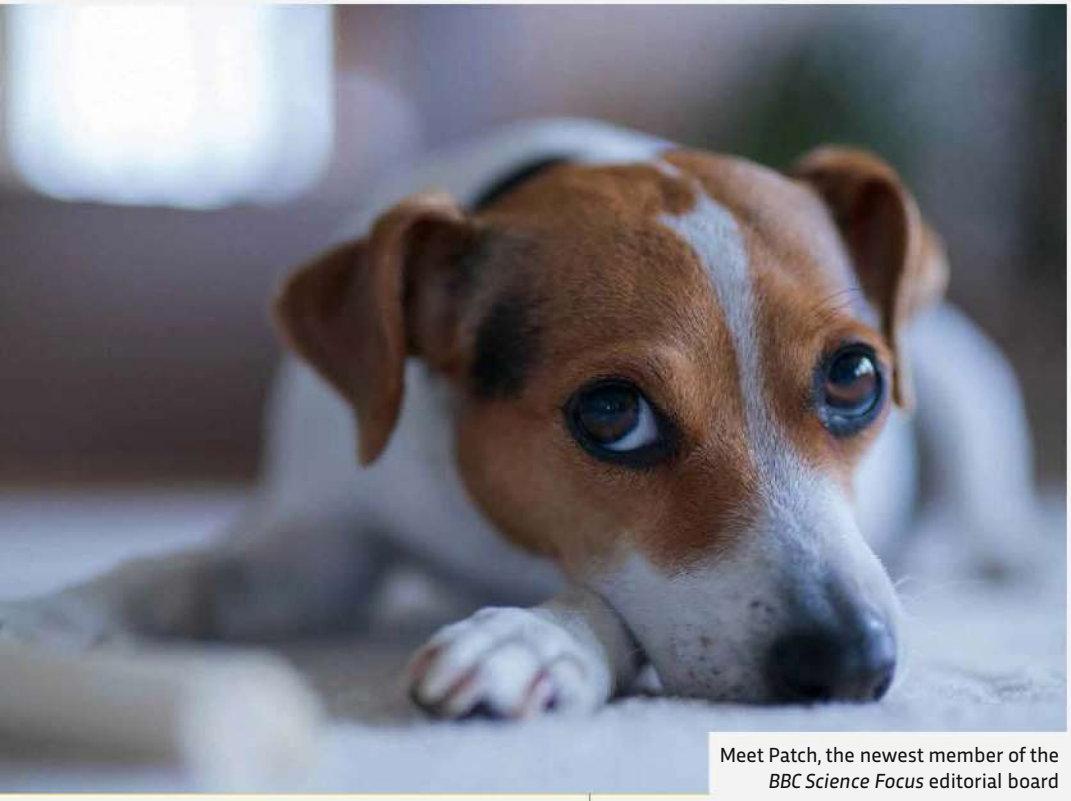
A question unanswered

It was with delight that I started reading Prof Stephon Alexander's column, 'Who's afraid of the Big Bang singularity?'. In it he asked, "Why does something exist rather than nothing?" What a fabulous question. Which is why it's such a shame the column didn't answer it.

I expected a discussion about the absolute origin of space, time and matter. Yes, we

"IF THE SUN COLLAPSED AND BECAME A BLACK HOLE RIGHT NOW, EARTH WOULD JUST KEEP ON ORBITING"

DR KATIE MACK, P28



Meet Patch, the newest member of the *BBC Science Focus* editorial board

GETTY IMAGES X2

agree it all blasted forth from a singularity, or as Prof Alexander discussed, bounced back and forth from repeated Big Bangs (cyclic inflation). That's all very well. But I actually don't care if space, matter and time bounced back and forth like a ping pong ball. Where did it come from originally? Was it creation from nothing?

I actually did think the column was very interesting. It just didn't, in my opinion, answer its initial question.

Elizabeth Gammon, MA, MS, PhD, via email

No dogs allowed

Was the Summer issue meant to be about science or a special issue to commemorate Crufts? The cover feature 'The secret life of dogs' was 16 pages long and contained very little science – most of the points made are common knowledge. Two whole pages were devoted to dogs using 'puppy eyes' to manipulate us, and there were further irrelevant points on how to upgrade your dog's life and whether crates are good or bad for them.

These are just prescriptive articles that are better suited to a dog magazine.

Roger Webber, via email

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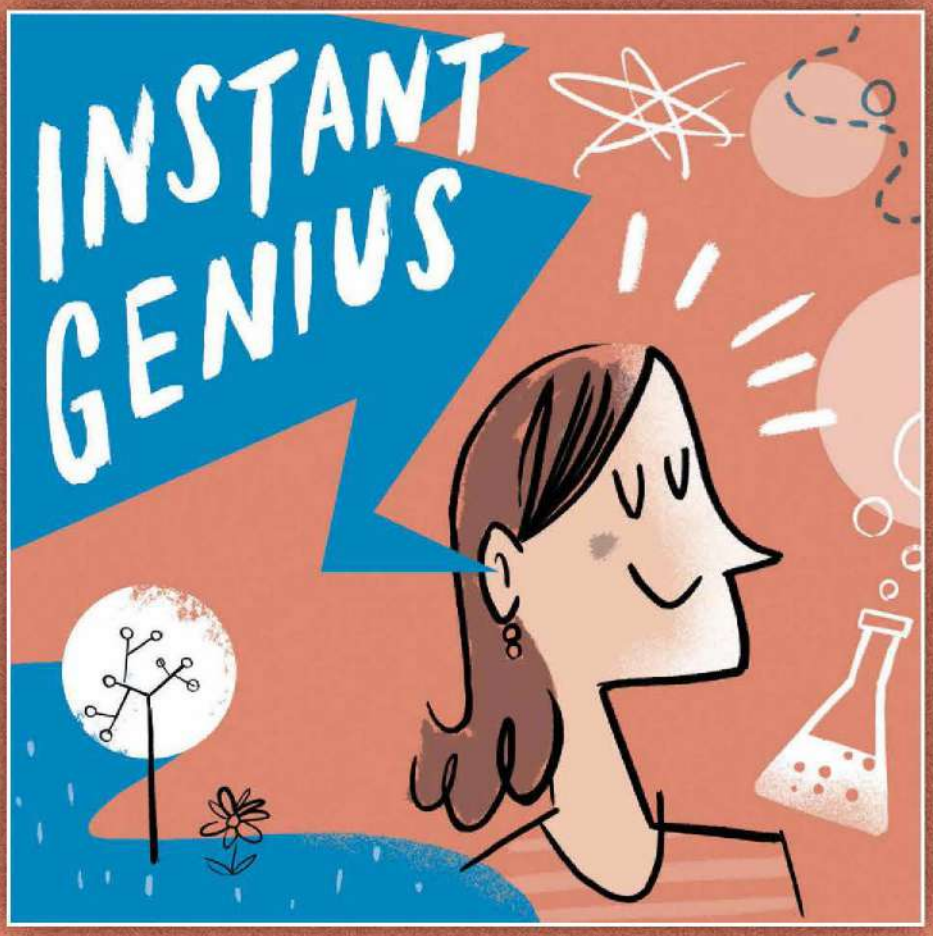

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Dr Tanja Radu

NUCLEAR WASTE
with
Dr Lewis Blackburn

PERFECTIONISM
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Dr Thomas Curran

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"The time has come to pursue platelet factors in brain health and cognitive enhancement"

Dr Dena Dubal **p17**

The Himalayas have a huge tectonic shift to thank for their current heights. But they may have started out higher than we think

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FOREVER YOUNG

Three teams discover a treatment for reversing the ageing process in mice **p16**

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NEUROSCIENCE

SCIENTISTS UNCOVER HOW YOUNG BLOOD REJUVENATES AGEING BRAINS

Injections and exercises that send platelets to your brain could help you become younger

ABOVE The possibility of reversing the effects of ageing has huge potential

ABOVE RIGHT The image on the left shows areas of age-related inflammation (in yellow and green) in an old mouse's brain. The image on the right shows an old mouse's brain after being treated with PF4

The alluring fantasy of an easy way to reverse ageing may soon become reality, thanks to remarkable new findings by neuroscientists.

Three interventions are already known to slow down, and even reverse, the biological process of ageing: transfusions of young blood; injections of a hormone produced in our brains, kidneys and livers called klotho; and physical exercise.

But there's one important thing that connects all three of them: platelets. Platelets are blood cells that sound your immune system's alarm when your body is wounded and form clots to help you heal.

Scientists working at two institutions in different parts of the world have discovered that platelet factor 4 (or PF4), a group of molecules released by activated platelets, is the crucial last step in delivering the benefits of these three interventions to the brain. What's more, PF4 can even help the brain reverse its age.

PF4 is released following injections of blood plasma (blood without the red blood cells) or klotho, and also by exercising.

When 22-month-old mice – the equivalent to 70-year-old humans – were injected with the blood plasma from young mice, the resulting release of PF4 reversed their cognitive age.

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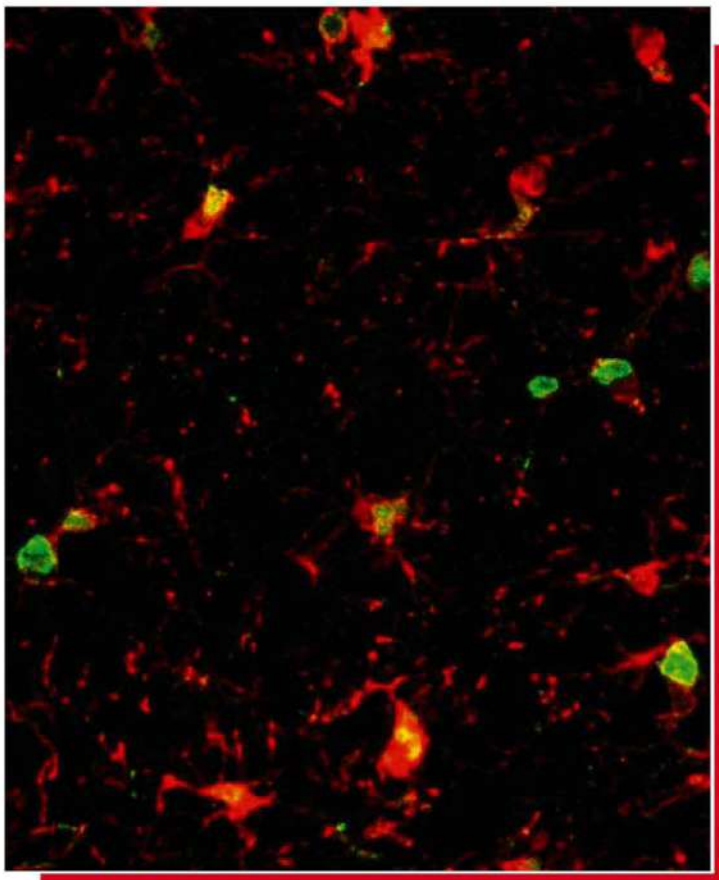
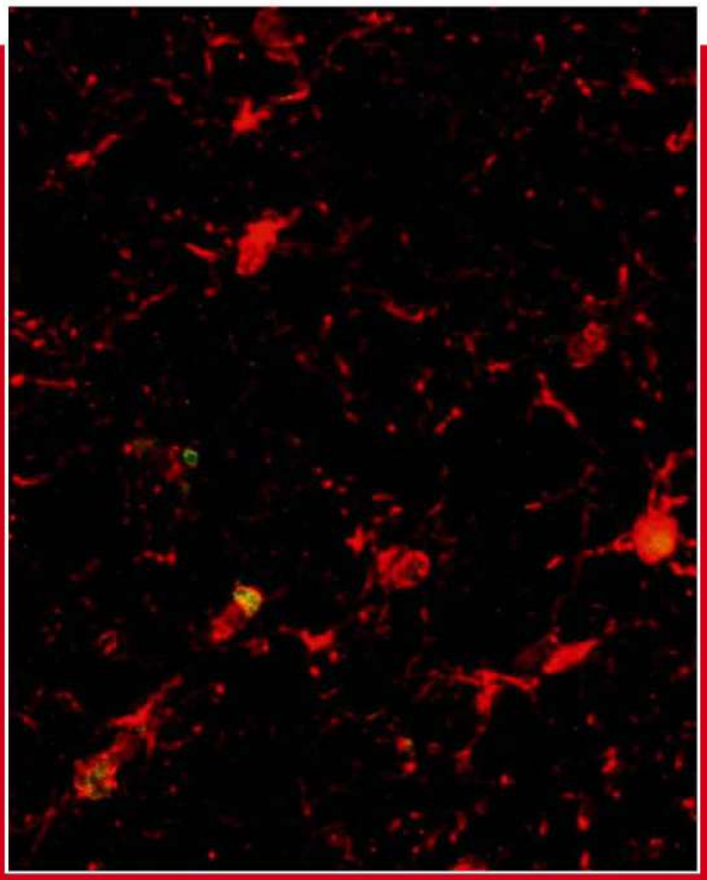




In fact, PF4 brought the age of the mice down to the equivalent of someone in their late 30s or early 40s. When the same procedure was performed on young mice, however, they became smarter.

Each of the discoveries was made independently by three research teams from two institutions. But when they realised they had all identified PF4 as the key ingredient behind these benefits, the teams joined forces to publish their papers at the same time.

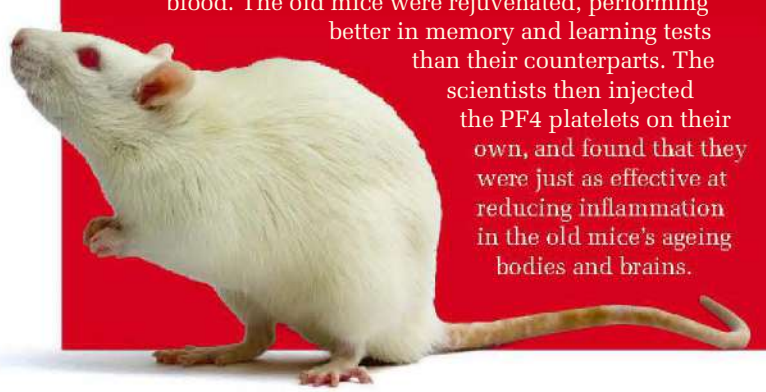
The studies on young blood and klotho injections were conducted by two teams working at the University of California San Francisco (UCSF). Scientists at the University of Queensland in Australia conducted the study on exercise. The three papers their work led to have been published in the journals *Nature*, *Nature Aging* and *Nature Communications* respectively.

"When we realised we had independently and serendipitously found the same thing, our jaws dropped," said Dr Dena Dubal, the UCSF professor who led the study on klotho.

"The fact that three separate interventions converged on platelet factors truly highlights the validity and reproducibility of this biology. The time has come to pursue platelet factors in brain health and cognitive enhancement."

Washed afresh with young blood

In studies on ageing, scientists often transfuse blood from a young mouse into an old mouse via a procedure known as parabiosis – surgically connecting two mice together. Doing so allows scientists to see how blood from one (young) mouse can affect another (old) one. It's how we know that young mouse blood can give old mice more resilient muscles and flexible brains. However, the team at the UCSF Bakar Aging Research Institute found that plasma alone could mimic these benefits. They injected old mice with young blood plasma, which contains more PF4 than old blood. The old mice were rejuvenated, performing better in memory and learning tests than their counterparts. The scientists then injected the PF4 platelets on their own, and found that they were just as effective at reducing inflammation in the old mice's ageing bodies and brains.



GEOLOGY

NEW STUDY FORCES RETHINK ON HOW THE HIMALAYAS BECAME SO TALL

A giant tectonic shift helped the mountains gain height, but they were big before that

How did the Himalayas become so high? Don't worry if you don't know, because it turns out leading scientists don't either. A new study has revealed that the Asian mountain range didn't reach its dizzying heights the way we thought they did: as a result of a huge tectonic collision.

The summit of Mount Everest – the tallest in the Himalayas and considered the highest point on Earth – sits at a height of 8,849m (29,032ft) today.

But the scientists behind the new study have worked out the height of the Himalayas before the tectonic collision thought to have caused their formation. They found that, while the collision did make them taller, the Himalayas were already very tall – and no-one knows why.

"Experts have long thought that it takes a massive tectonic collision, on the order of continent-to-continent scale, to produce the sort of uplift required to produce Himalaya-scale elevations," said the study's first author Daniel Ibarra, now assistant professor at Brown University, in the US, but previously of Stanford Doerr School of Sustainability. "This study disproves that and sends the field in some interesting new directions."

Published in the journal *Nature Geoscience*, the study describes how scientists at Stanford Doerr School of Sustainability, working with scientists from China University of Geosciences, discovered a new way to measure the past altitudes of sedimentary rocks, inspired by an existing technique used to examine meteorites. By measuring the isotopic composition of the Himalayan rocks, the scientists were able to determine their ancient altitude.

It works like this: warm air on the leeward side of a mountain (the side sheltered from the wind) rises and cools, before condensing into rain and snow. As the air rises, the chemical composition of its rain changes. Heavier isotopes (variations of elements like oxygen that contain more neutrons) drop from the clouds first, while lighter isotopes drop nearer the summit.

What the scientists found through this three-year analysis was that the Himalayan mountains at the edges of tectonic plates were already around 3,500m (11,480ft) tall before the collision. This is a lot higher than previously thought – more than 60 per cent of their present-day height, in fact.

The results mean that ancient climate models around the Himalayas will need to be recalibrated, perhaps leading to new theories on the ancient climate of Southern Tibet. Other mountain ranges like the Andes and the Sierra Nevada will likely be re-assessed too.

"This new understanding could reshape theories about past climate and biodiversity," said Ibarra.

ABOVE The history of how the Himalaya mountains gained their imposing immensity may require a rewrite

GETTY IMAGES X2

NEUROSCIENCE

SCIENTISTS A STEP CLOSER TO DECODING THE CREATIVE PROCESS

Neuroscientists have gained an insight into how we choose between ideas by playing a word association game

If you prefer originals to remakes, you're probably a more creative thinker, according to a new study, published in *American Psychologist*. Not only that, but the study suggests that more you like an idea you're coming up with, the quicker you'll decide to pursue it.

"Our results indicate that the subjective evaluation of ideas plays an important role in creativity," said Emmanuelle Volle, a neurologist at the Paris Brain Institute and part of the team behind the study. "We observed a relationship between the speed of production of new ideas and participants' level of appreciation of these ideas. In other words, the more you like the idea you're about to formulate, the faster you come up with it."

Creativity is a complex and poorly understood process, but the team behind this study defined it as the ability to produce original and relevant ideas in a given context, in order to solve a problem or improve a situation. Using that definition, they set out to investigate what makes us choose some ideas over others.

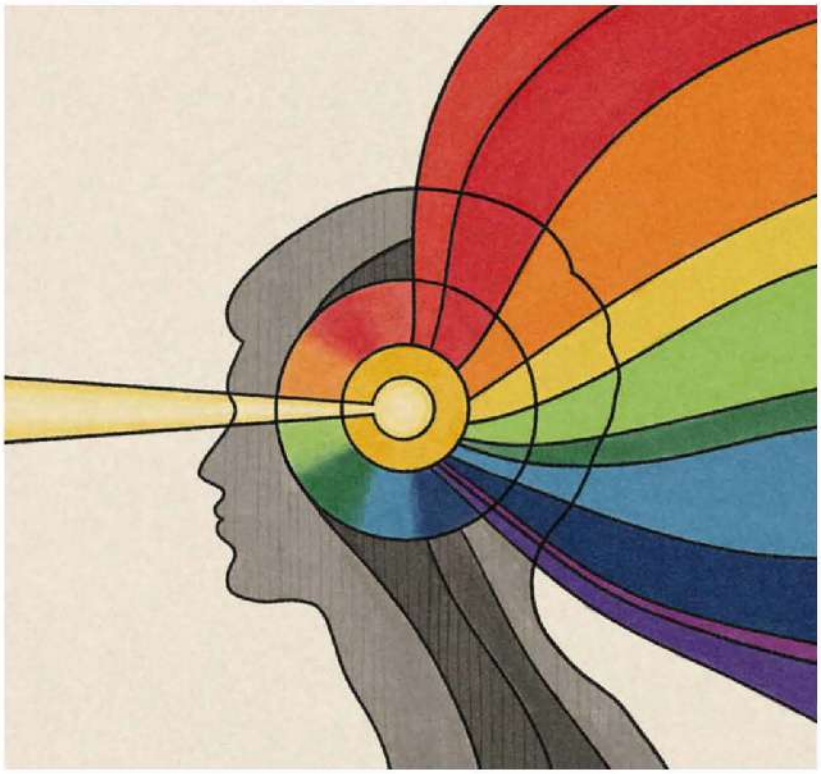
"We observed a relationship between the speed of production of new ideas and participants' level of appreciation of these ideas"

To do this they asked 71 volunteers to take free association tests, where they were asked to match words in the most audacious way possible. The volunteers were then asked to rate their associations according to how relevant and original they seemed.

The study shows that the importance of originality and relevance varies between individuals. "It all depends on their experience, personality and probably their environment, said Volle. "Some favour the originality of an idea over its relevance; for others, it's the other way around. However, preferring either originality or relevance has a role in creative thinking: we have shown that individuals inclined to original ideas suggest more inventive concepts."

The team also attempted to model the creative process in a computer. The creative process has three dimensions that they say can be reproduced mathematically: exploration (the ability to remember old ideas and alter or combine them in new ways); evaluation (assessing the ideas you're coming up with); and selection (choosing which ideas to pursue and share).

The model predicted the speed and quality of participants' creative proposals based on their preferences measured in an independent task. These results suggest that it might one day be possible to precisely describe what happens in the brain when someone is trying to be creative. Understanding this might help us develop ways to improve our creativity through cognitive exercises and design workplaces that are better at fostering creativity. "All these questions remain open, but we firmly intend to answer them," said one of the study's co-authors Alizée Lopez-Persem.



BELOW Figuring out how you choose between all the ideas you already have filling your head is an important step in understanding the creative process

PALAEONTOLOGY

COLOSSAL EXTINCT WHALE COULD BE THE HEAVIEST ANIMAL OF ALL TIME

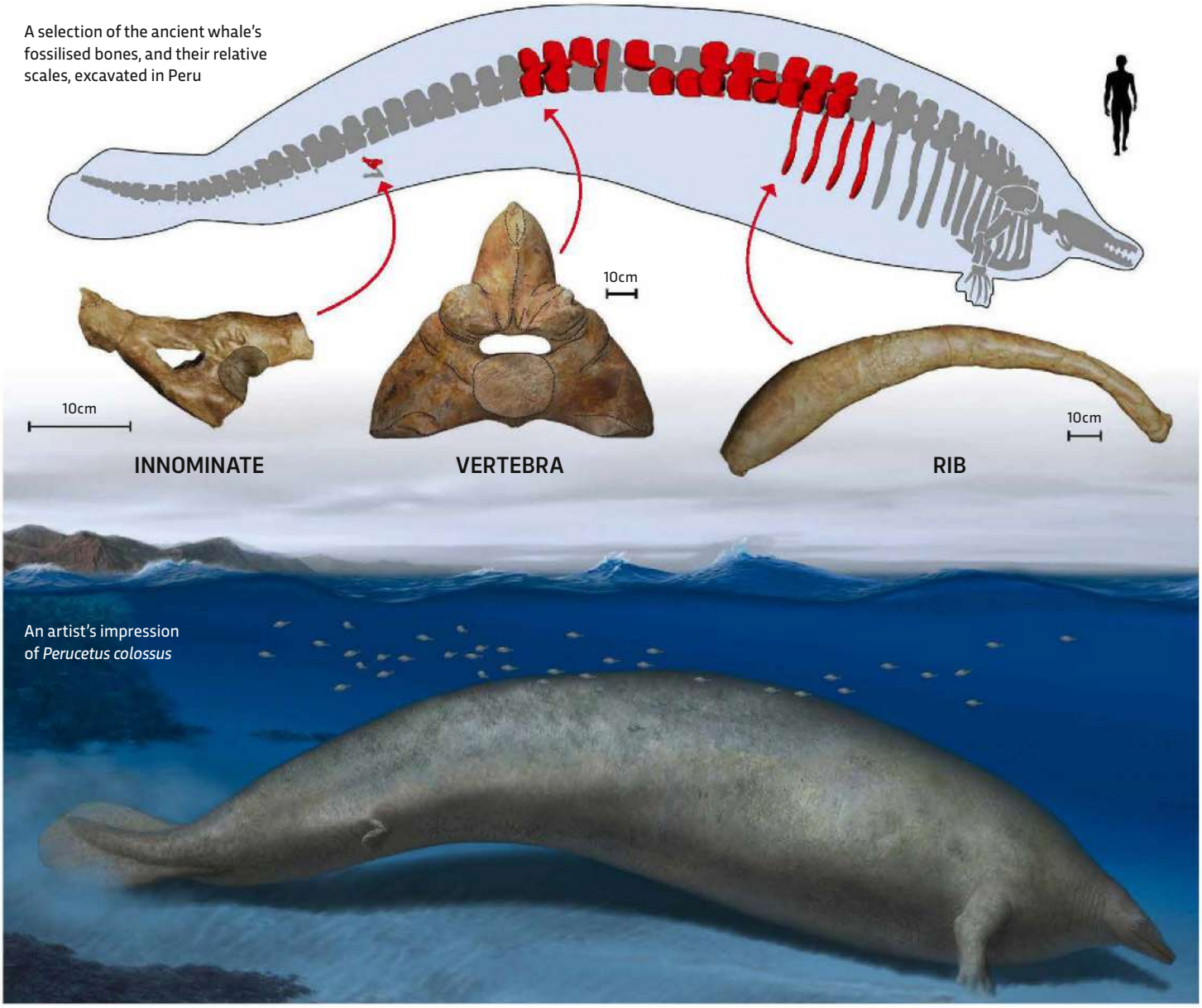
The giant mammal had a tiny head but enough mass to eclipse the blue whale

An ancient species of whale known as *Perucetus colossus* has been described as the heaviest animal to have ever lived. The news, announced in a study published in *Nature,* knocks the current holder of that title, the blue whale, from its top spot.

P. colossus lived during the Eocene epoch, between 33-54 million years ago, when rising temperatures saw a plethora of new animals evolve, including the first horses, bats and whales.

With an estimated length of 20m (66ft), *P. colossus* was approximately the same size as a blue whale. But its body mass, thought to be somewhere between 85 and 340 tonnes, had the potential to easily eclipse that of today's blue whale. The ancient whale's skeletal mass alone was two to three times that of the blue whale (3,500kg/7,700lbs).

A selection of the ancient whale's fossilised bones, and their relative scales, excavated in Peru



An artist's impression of *Perucetus colossus*

GIOVANNI BIANUCCI X2, ALBERTO GENNARI, GETTY IMAGES

The fossilised bones of *P. colossus* were excavated in Peru

P. colossus was discovered in Peru 13 years ago by palaeontologist and co-author on this study Mario Urbina from the University of San Marcos' Natural History Museum in Lima. Since then, scientists have been estimating the whale's size and weight based on its partial skeleton.

"We kept the project ultra-secret during all these years," Dr Eli Amson, another of the paper's authors and mammal fossil curator at Stuttgart State University of Natural History, Germany, told *BBC Science Focus*.

Given its enormous size, there is much speculation over *P. colossus*'s ability to move, not to mention its tiny head.

"The head of *Perucetus* is a complete mystery," Amson said. "[And] *Perucetus* was most likely not an agile swimmer – can you imagine the inertia of such a tremendous body? Considering its enormous mass and swimming style, *Perucetus* moved very slowly."

In evolutionary history, scientists previously thought that cetaceans – a group of mammals that includes dolphins and whales – might have been part of the movement of terrestrial mammals back to the ocean. Previous fossil records have helped to identify adaptations to a marine environment – including a trend towards gigantism. One of the benefits of being so big is better body temperature regulation.

The new addition of *P. colossus* to the fossil record reveals much about marine evolution. In fact, the estimations of the ancient whale's size suggest that cetaceans reached peak body mass 30 million years before we thought.

MEDICINE

WALKING JUST 5,000 STEPS A DAY IS ENOUGH TO LOWER YOUR RISK OF DEATH

The 10,000 steps goal is a myth. Depending on your age, you could reap the benefits from less than a quarter of that figure

If you've ever used a wearable exercise monitor, you may be familiar with the celebratory buzz when you hit your daily target of 10,000 steps – and the disappointment when your count falls short of that mark.

But a new study reveals that you begin reaping health benefits when you take as few as 3,967 daily steps – benefits that have the potential to reduce your risk of dying from a range of causes. The research also found that a minimum of 2,337 steps was enough to reduce your risk of death from cardiovascular diseases specifically.

Published in the *European Journal of Preventive Cardiology*, the paper brought together data from 17 existing studies involving 226,889 people.

It's the first to assess the impacts of walking up to 20,000 steps a day, as well as whether the risk of dying differs depending on age, sex and where in the world people live.

The study found that the more you walk, the better – regardless of your age, sex or the climatic conditions in your home region.

In fact, the scientists behind the study found that every additional 1,000 steps a day you take on top of the minimum reduces your risk of death by 15 per cent.

These benefits keep increasing with no upper limit, according to the scientists. The data reveals that for those walking fanatics who take as many as 20,000 strides a day, the benefits only continue to build.

Insufficient physical activity is the fourth biggest risk factor for death across the world, according to the World Health Organization – being associated with 3.2 million deaths a year.

You may need to reset your daily step count target in light of this research

This is something the study's lead author, Prof Maciej Banach of the Medical University of Lodz, Poland, and Johns Hopkins University School of Medicine, America, hopes to change.

"In a world where we have more and more advanced drugs to target specific conditions such as cardiovascular disease, I believe we should always emphasise that lifestyle changes, including diet and exercise [...] might be at least as, or even more, effective in reducing cardiovascular risk and prolonging lives," he said.

The study's authors say further research is needed and should explore the benefits of more intensive exercise such as running marathons. These studies may also look into the specific benefits of walking for different ages and races, and people with existing health problems.

NATURE

SEE THE WINNING IMAGES FROM THE ECOLOGY AND EVOLUTION PHOTO COMPETITION

From zombie fungus to dinosaur blood, the images highlight the bizarre and beautiful in nature

The photography competition run by the journal *BMC Ecology and Evolution* is unlike any other. As well as seeking out stunning images of the natural world, it also attempts to highlight the people behind the research depicted in those images. This year (the competition's third) fungi stole the show, with a colourful image of the invasive orange pore fungus (top right) growing in the Australian rainforest claiming the overall prize.

"Despite its innocent and beautiful appearance," said winning photographer Cornelia Sattler, "[...] it is important to closely monitor this fungus, whose spores are often transported by humans, in order to safeguard the biodiversity of Australia."

The two winners in the Plants and Fungi category also featured fungi, including a macabre image of the zombie-ant fungus (bottom right).

But the competition, which only accepts submissions from experts affiliated with a research institution, also celebrates the ecologists, biologists and palaeontologists at the heart of science stories. From the palaeobiologist peering into dinosaur blood from behind the microscope to the beekeepers producing honey to fund chimpanzee conservation in Guinea, the photos capture the work of the people who commit their skills to the natural world in extraordinary detail.

1

1. Runner up: Research in Action Researchers from the University of Glasgow conduct a necropsy on a humpback whale carcass. The dead whale washed ashore at the Loch Fleet Nature Reserve in northern Scotland, UK, in May 2023. *Photo by James Bunyan from Tracks Ecology.*

2. Overall winner The fruiting bodies of an orange pore fungus (*Favolaschia calocera*) grow on deadwood in the Australian rainforest. Research shows that 82 per cent of Australian wildlife is under threat from various invasive species. *Photo by Cornelia Sattler of Macquarie University.*

3. Winner: Research in Action A team from the Hoey Reef Ecology Lab deploy a Remotely Operated Vehicle (ROV) in the Coral Sea Marine Park, off the coast of Queensland, Australia, to conduct surveys at depths beyond the reach of divers. *Photo by Victor Huertas of James Cook University.*

4. Runner up: Paleoecology A microscope image of an extracted diplodocid dinosaur blood vessel, surrounded by the extracellular matrix of cell remnants that are approximately 150 million years old. *Photo by Dr Jasmina Wiemann, University of Chicago*

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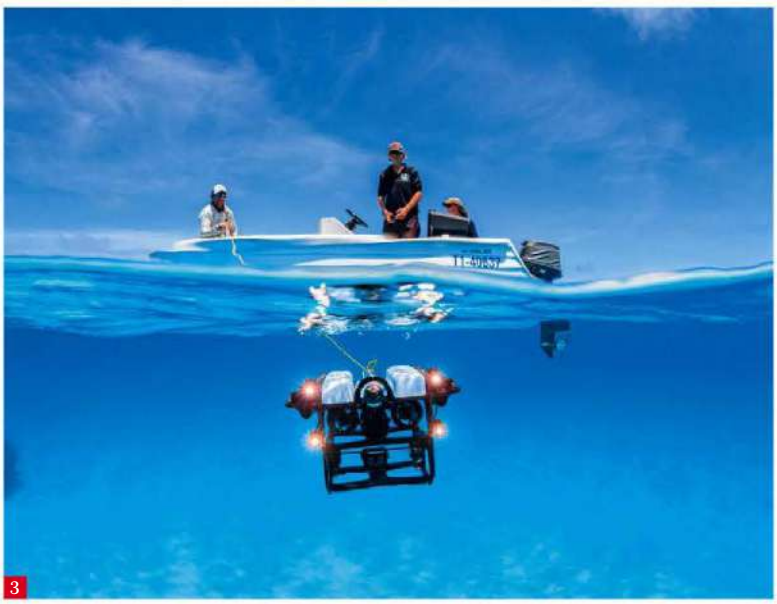

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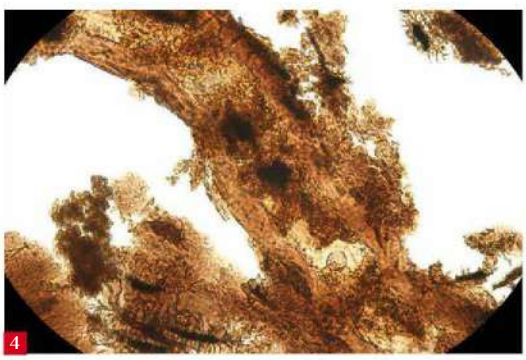

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5. Winner: Plants and Fungi A fungus parasitising the fruiting body of a zombie-ant fungus. Zombie-ant fungi can manipulate the behaviour of their hosts, compelling them to find a spot that will help the fungus to spread. *Photo by João Araujo of the New York Botanical Garden.*

HORIZONS

REPRODUCTION IN SPACE

Conceiving babies in space poses many problems. One company is trying to solve them

DR EGBERT EDELBROEK
Dr Egbert Edelbroek is the founder and CEO of SpaceBorn United

Solutions to all of the other problems space exploration poses are meaningless if we can't find a way to reproduce safely in space

GETTY IMAGES

Everyone, it seems, is fixated on space exploration right now. NASA, in collaboration with the Canadian, Japanese and European space agencies, is working on the Gateway programme to build a human-tended space station in lunar orbit; and various billionaires are continuing with their plans to establish colonies on other planets and launch space tourism enterprises.

Assuming they're successful, these projects would represent the first, tentative steps humanity takes away from Earth and further out into space. But if surviving among the stars is the long-term aim of such endeavours, there's a hurdle that needs to be overcome in the short term: human reproduction. Making babies in space, whether by artificial means or naturally, is fraught with issues, most notably radiation and gravity.

SpaceBorn United, a company based in the Netherlands, is trying to address these issues. To that end it has developed a miniaturised IVF and embryo incubator, which is ready to be launched on a mission to assess humanity's ability to reproduce in space. SpaceBorn United's CEO Dr Egbert Edelbroek explains more…

WHAT IS SPACEBORN UNITED'S GOAL?

We intend to perform conception and early embryo development in space. If we want to have human settlements on Mars, for example, and if we want to make those settlements really independent, that requires solving the reproduction challenge. Nobody knows if the gravity level of Mars, which is much less than the Earth's, will be sufficient for healthy embryo development.

Initially we were only focusing on learning about partial gravity effects. But we learned that there is another goal that we can contribute to: improving IVF on Earth. Doing IVF in space at different gravity levels will provide crucial insights that can increase the success of IVF treatments. This includes ground-based tests, which we're discussing with the European Space Agency (ESA), as they have facilities to simulate microgravity or partial gravity. We're excited that we can contribute to this.

AND WHAT POINT ARE YOU AT? HOW CLOSE ARE YOU TO ACHIEVING THIS GOAL?

We're interested in the development of artificial wombs as they might contribute to solving the reproduction challenge in space (currently these are being developed for premature babies rather than for use in space). A research team in Israel has succeeded in getting mouse embryos to grow outside of a natural womb for 11 days. The target we're aiming for is five days. [The legal limit on human embryo research in the UK is 14 days].

Of course, the first step is also using animal models, so mammalian gametes and embryos. But eventually we need to transition to working with human gametes. For the last five to six years, we've focused on this first stage of reproduction – and probably will for the next five to six years. This includes conception and early embryo development. But people are often interested in our longer-term mission to achieve childbirth in space. Our timelines were a little bit ambitious, though. We'll continue to focus on that first stage, but, eventually, of course, somebody needs to do childbirth in space – maybe we'll do it soon.

HOW DOES IVF IN SPACE ACTUALLY WORK?

We're using microfluidic technology to miniaturise and re-engineer existing embryo incubators. These were never designed to be small or low mass. But now we've made them into a CD-ROM-sized disc, full of micro channels. Different chambers hold sperm fluids and female eggs, and you can programme the complete conception process on that disc.

There's been a lot of progress in terms of hardware. Our first prototype is finished and ready to go into space. We're very proud of that.

ARE YOU WORKING WITH ASTRONAUTS ON NATURAL CONCEPTION, OR WILL THAT COME MUCH LATER?

We know that natural conception in space is not a good idea, ethically or medically. But there's this space tourism sector opening up and accelerating. That will be a magnet

“If we want to have human settlements on Mars, and make them really independent, that requires solving the reproduction challenge”

for couples that want crazy bragging rights, like “Hey, we have the very first baby conceived naturally in space.” But that’s not a good idea. We actually wrote a paper about this, in collaboration with Cranfield University, to boost awareness of the risks of natural sex in space. It went a little bit viral.

YOUR LAUNCH IS SCHEDULED FOR 2025. DO YOU THINK PLANS TO SEND HUMANS TO COLONISE MARS BY 2050 ARE REALISTIC?

I think there are so many reasons to leave Earth and expand humanity’s comfort zone. Exploration has given huge benefits to humanity. But there’s another reason [to leave Earth]. We’re not treating the planet nicely, which has led to climate change, and there are potential problems with asteroids, artificial intelligence, even nuclear threats. So it would be a good idea to have a back-up plan.

But can we do it in 25 years… Who knows? Artificial intelligence seems capable of speeding up a lot of things, but, of course, it’s also about budgets. More and more private companies, including a lot of billionaires now, are taking part in the new space race so it’s further accelerating.

However, until recently space companies have focused on the engineering and hardware necessary to get people to space, not the reproductive part. The main reason for this is that it’s ethically complex and sensitive. But it’s pretty pointless to spend all those billions of dollars, not to mention all that time and effort, on preparing settlements on Mars if you can’t overcome the reproductive challenge. There will be people living in space and possibly on Mars, so there is a life science part that has been happening in the margins. We’re adding to that.

LIKE THOSE RACING TO THE MOON OR MARS, ARE THESE BABY STEPS IN A DIFFERENT KIND OF SPACE RACE?

We have been approached by countries who want to put themselves on the map with some unique achievement in space. And it seems that being able to claim that their nation enabled the very first human baby to be conceived in space is attractive for them, in that regard. In the longer term, enabling the first childbirth in space is another very big step, of course.

Some other companies are working on space conception with frog eggs, fruit flies and sometimes small mammals, like mice or rats. But nobody else has the aim of doing this with human gametes and embryos.

COMMENT

THE SECRET TO COMEDY MAY BE A BUSY JUNCTION IN YOUR BRAIN

A joke walks into a brain and a psychologist asks: "So what makes you so funny?"

Jokes and humour are often thought of as frivolous and unimportant. In a way, this is understandable: they are, by definition, not serious. If the lawyer defending you in court couldn't stop wisecracking, you'd be understandably alarmed.

But the common impulse to regard humour as inconsequential, is a mistake. Humour, jokes and laughter, have a vital role to play in human behaviour and interaction.

Humour is a powerful part of social bonding: we're 30 times more likely to laugh with others than when alone. Humour is heavily intertwined with human mating behaviours. Humour is the brain's way of displaying prowess and success, the cognitive equivalent of antlers on a stag. Also, humour and laughter are genuinely beneficial for health via their stress-relieving properties.

But, what's happening in our brains? Why do we respond, in such powerful and rewarding ways, to things that are objectively nonsensical?

Scientists have spent years studying this, which is to their credit (making people laugh isn't an ability normally associated with professional scientists). A substantial amount of data has been generated regarding how humour works in the brain and on the various types of recognisable jokes that induce it.

While jokes can manifest in a wide range of ways (semantic jokes, linguistic jokes, static and dynamic visual jokes and more), unsurprisingly, the most basic recognised joke is the pun.

Verbal puns, the most familiar type, are where specific linguistic elements convey different meanings, simultaneously. For example, 'Why did the golfer wear two pairs of trousers? In case he got a hole in one.' Here 'hole in one' has two possible interpretations. Both are equally valid, simultaneously.

DR DEAN BURNETT

Neuroscientist Dean explores the psychology behind emotions in his latest book Emotional Ignorance *(£14.99, Guardian Faber).*

Interestingly, puns are often the go-to jokes scientists use when studying humour. We may not actually laugh at them, but their simplicity and familiarity mean most people recognise the humour in puns, however feeble it may be. So, the brain's humour processes are still engaged.

But where does humour arise from in the brain? According to the data, everywhere. This is because jokes and other humorous stimuli typically include many sensory elements, as well as language, memory, emotion, analysis, extrapolation and so on. These are all processed by disparate neurological regions and networks.

However, considerable research points towards a part of the brain where everything to do with jokes converges, forming a specific system for recognising humour. This system is composed of regions occupying the junctions between temporal, occipital and parietal lobes.

This system seemingly detects and resolves incongruity. Our brains know how things, like language and behaviours, should work. But, in the real world, many things don't conform to our expectations. It seems our brains have evolved a system to recognise when this happens.

If normality is subverted, it means we don't know what's going to happen, which creates cognitive tension. However, the system that recognises incongruity seemingly also resolves it, by providing an explanation, or at least a confirmation that the incongruity has no negative consequences. This removes the uncertainty, dispersing the tension.

Our brain approves of this. It means potential danger has been removed, we've learned something new, we've expanded our mental model, and more. So, we experience a rewarding feeling.

Thanks to these complex systems in our brains, humour can be derived from something being surprising, unexpected or wrong in some way, as long at it's resolved without negative consequences.

If the incongruity is not resolved, however, humour is absent. If the answer to 'Why did the golfer wear two pairs of trousers?' is 'in case the metal owl that lives in his gold bag attacks him', that's not funny. There's unresolved incongruity. This would explain why surreal humour is often so hard to get right.

This is also why, unlike music, jokes struggle to have the same impact when repeated. The resolving of incongruity is a key part of humour. If it's familiar, the incongruity has already been resolved.

Humour is a uniquely human phenomenon with many other complex variables that affect it. Status, emotion, motivation, social cognition, memory, arousal and so on. But, according to the latest science, the detection and resolution of incongruity is its neurological bedrock. Humour is essentially our brain going, "This isn't how things usually work… but I'm okay with it!"

"Humour, jokes and laughter have a vital role to play in human interaction"

ILLUSTRATION: BERNARD LEONARDO

COMMENT

THERE'S A MONSTER IN OUR BACK YARD, BUT IT'S NOTHING TO WORRY ABOUT

Not even light can escape the black hole at the centre of our galaxy. But we'll be fine... as long as we keep a safe distance

In May 2022, astronomers took the first photograph of the monster in our backyard: Sagittarius A*, the supermassive black hole, four million times as massive as the Sun, lurking right in the middle of the Milky Way.

The Event Horizon Telescope, a global collaboration that links observatories around the world to combine data into a single ultra-high-resolution image, specialises in capturing the 'shadows' of supermassive black holes.

Rather than blocking light, a black hole makes its shadow by bending the space around it so violently that any light that passes near it – for instance, the bright glow of the matter whirling around in its accretion disc – is distorted and redirected, with some of it being pulled into the object itself.

This distortion wraps the light around the hole like a cloak, but leaves a gap in the centre, which appears to an observer as... well, a black hole. The shadow is dark, not because the light was blocked, but because it has been consumed.

The event horizon from which the telescope takes its name, is the spherical boundary around the black hole that marks the point of no return: anything that crosses that boundary is drawn inexorably into the centre of the black hole.

At the event horizon, the escape velocity (that is, the speed required to escape the hole's gravity) equals the speed of light. Einstein's theory of Special Relativity sets light speed as a hard limit: nothing in the Universe can exceed it, so nothing can escape a black hole.

The image of Sagittarius A* further confirmed for us that not only do supermassive black holes exist, but that relativity's rules are (literally) inescapable.

Of course, Sagittarius A* consumes more than just passing light. Like all supermassive black holes, it pulls in whatever gas, dust and superheated plasma might be lingering close to its horizon. Every once in a while, to the great delight of astronomers, supermassive black holes consume entire stars, which, when ripped apart by the tidal forces, emit bursts of X-ray light.

So far, all we've seen Sagittarius A* eat is a couple of clumpy clouds of gas, but we know it wouldn't be picky.

So, should we be worried? Is having an insatiable four-million-solar-mass behemoth sitting in the centre of our galaxy like a drain hole in a cosmic bathtub? Is it something that keeps astronomers up at night?

No. Because, despite their reputation, black holes (of any size) are completely harmless to anyone with the good sense not to approach them. It comes down to a subtlety of how gravity works at different distances.

ILLUSTRATION: MATT HOLLAND

“If the Sun collapsed and became a black hole right now, Earth would just keep on orbiting”

According to Einstein’s theory of General Relativity, what we experience as gravitational pull is the result of the space around a massive object being curved toward it, which alters how objects and light move through that space.

All matter (and energy) bends space to some degree, and because gravity is an infinite force, the space you’re in right now is affected at some infinitesimal level by the gravity of every other thing in the Universe.

The special thing about a black hole is that the curvature very close to the singularity at its core is so extreme that, within the event horizon, motion away from the black hole becomes impossible. In other words, any path away from the singularity curves back on itself.

Even in the near vicinity of the horizon, extreme tidal forces can destroy anything that comes too close. But once you’re outside of that danger zone, the spatial curvature looks identical to what you would experience an equivalent distance from any ordinary star or large clump of matter.

If the Sun collapsed and became a black hole right now, Earth would just keep on orbiting, completely unaffected. It would get very cold and very dark, but we’re far enough away that there would be no gravitational measurement we could do that would tell us that the black hole was not just an ordinary (though disturbingly dark) star.

When it comes to Sagittarius A*, the supermassive black hole at the centre of the Milky Way, its gravitational influence on our Solar System is not only non-threatening, it isn’t even particularly important for our orbit around the Galactic Centre.

The clump of stars, gas and dust at the centre outweighs it by orders of magnitude, and that’s not even counting all the ghostly dark matter filling all that space. Our galactic orbit, along with the orbits of all the other stars in the disc, remains safe.

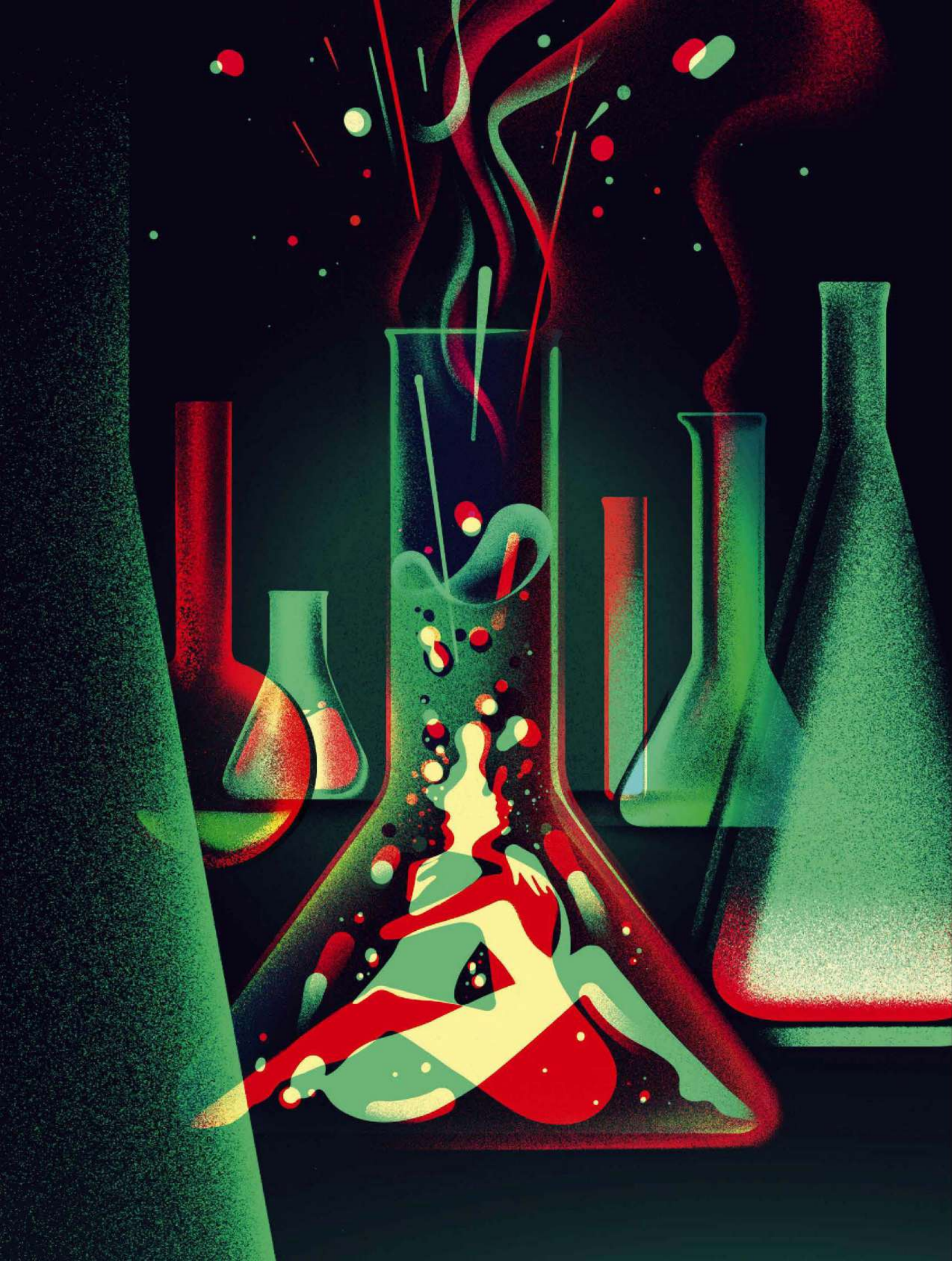
For now, at least.

In about four billion years, the Milky Way will collide with the Andromeda Galaxy, scattering stars and planets across the cosmos in chaotic streams like tossed glitter, and likely causing the supermassive black holes at the two galaxies’ centres to spiral together and merge.

There’s no telling what will have happened to our local clump of stars by then, but, hopefully, somewhere far across the cosmos, someone will have their camera ready and capture a truly amazing view.

DR KATIE MACK

(@AstroKatie) Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.



COMMENT

THINKING OF SEXUAL DESIRE AS AN ON/OFF SWITCH ISN'T HELPING ANYBODY

By taking the mystery and misunderstanding out of sexual desire, science can help you have a more fulfilling sex life

Sexual desire is often confused with both libido and arousal. These three terms are usually spoken about and used interchangeably, but are rarely fully understood.

Libido is commonly used to describe sex drive, but it's usually seen to be binary, so it's either high or low. Arousal is the collective term for the physical changes that enable the body to be ready for sex, such as raised heart and breathing rates, and increased blood flow to the genitals.

But in medical terms, desire is a person's want to have sex, which is a fluid situation.

Like many human behaviours, sex is a habit. Yet there is no normal frequency and amount of sex that's good or bad. Instead, frequency, duration and type of sex is down to what each individual finds pleasurable.

People want and have sex for many different reasons. Classically, sexual desire was thought to be a 'sex drive', with people having either a low or high sex drive. It was presumed that this was fixed and an inherent part of all of us. But this led to many women being mislabelled as having low sexual desire, simply because they didn't want as much sex as their partners.

> "Fulfilling sex is a behaviour that's cultivated, rather than being ever-present"

This theory was overtaken by the 'dual control model of sexual response'. This states that there are two independent processes occurring that feed into our sexual response. One is excitatory and activating, while the other is inhibitory and deactivating.

The balance between these two opposing processes determines a person's overall response in any given moment. Think of it like a car with an accelerator (excitatory) and brake (inhibitory). How much accelerator and brake are applied when it comes to sex will vary between people and also fluctuate within a person. People may have more accelerator or brake overall, but each situation will be different. So, desire is complex, individual and dynamic.

A more in-depth look at the science of sexual desire reveals that it can be split into two types: spontaneous desire and responsive desire. Spontaneous desire shows up instantly and can occur with or without stimulation. It's typically high when people are young and/or at the beginning of a new relationship or situation. In contrast, responsive desire is a reaction to an external stimulus (a book you're reading, perhaps, or having dinner with your partner) and tends to be greater in longer-term relationships, where spontaneous desire may have reduced.

These two types of desire are built into an alternative model that addresses women's sexual response. It acknowledges the two types of desire and explains that they may come before or after arousal. It better reflects how women feel about, respond to and experience sex. It also incorporates the key role of intimacy (being physically and/or emotionally close) and acknowledges how that's often a strong factor in motivating women to want to have sex.

Of course, there are also biological, psychological and social factors that can affect sexual desire. If you're suffering from a physical condition, such as aching joints, vulvodynia (a condition that causes pain, burning or discomfort in the vulva) or the genitourinary symptoms of menopause, which cause sex to be painful, you'll be instantly put off. You'll remember this pain the next time you have a sexual experience and be put off even more. This is your inhibitory processes dominating your excitatory processes and reducing your desire to have sex.

Nobody wants to do things they don't enjoy, whether that enjoyment hinges on physical or psychological factors. If a person doesn't feel comfortable – due to their body image, for example, or because they're in a strained relationship – they won't enjoy sexual experiences and this will affect their view of sex overall and their ability to feel sexual desire.

There are also external distractions that can inhibit desire. The routine of normal life (work needing to be done, food needing to be made, children needing to be looked after) can simply get in the way. A never-ending to-do list and constant tending to others' needs can quietly and consistently affect your body and mind's ability to produce responsive desire, let alone provide space for spontaneous desire to be felt.

Great, pleasurable and fulfilling sex is a behaviour that's cultivated, rather than being ever-present and automatic. And sexual desire is not something you either have or you don't; it's a more a fluctuating feeling that needs to grow and be nurtured. But this isn't fully understood by most people, which can leave them confused about their attitude to sex and lead to problems.

It doesn't have to be this way. Better education on the science of desire would give us greater insights into our sexual motivations and lead to happier and more fulfilling sex lives.

DR MICHELLE GRIFFIN

Michelle is the director of MFG Health Consulting, as well as a women's health expert and strategy advisor in women's health tech.

ILLUSTRATION: ADRIA VOLTA

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

Group exercise | Tech-free breaks | 20mph speed limits

REVIEW

GROUP EXERCISE: WHY WORKING OUT WITH OTHERS COULD BE THE KEY TO GREATER FITNESS

Science is revealing why you're better off getting a sweat on with a group of mates than you are by going solo

"People can, to some extent, outsource their self-regulation to the group, such that the same intensity of exercise feels easier in a group"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on X (formerly Twitter)* ***@BBCRealityCheck***

Sweating in the company of others has never been more popular, from yoga and spin classes to CrossFit and Parkrun. While some of us like to go it alone, millions of people use group exercise to stay fit and healthy. But is it possible that working out with others has advantages that an unaccompanied workout doesn't? Take a run through the research and it would seem so.

DO GROUP WORKOUTS MOTIVATE US MORE?

Studies have found that group exercise can be motivating in a way that solo workouts aren't. It also appeals to a broader set of people, bringing out the eye of the tiger in even the slouchiest of house cats.

It's why so many fitness companies have duly turned communal calorie-shifting into big business. The likes of CrossFit, Peloton and Les Mills are marketed as much for their community atmosphere as the effectiveness of their workouts. All three have gyms or sold-out classes the world over.

It's a similar story with Parkrun, the volunteer-run charity that organises 5km runs every weekend in towns and cities in over 20 countries. Parkrun began with a group of 13 runners in Bushy Park, London, in 2004. By 2013, researchers were studying its appeal for a paper in the *Journal of Public Health*, which found that it's particularly attractive to people who wouldn't describe themselves as runners.

IS THAT IT? COULD THE BENEFIT OF GROUP WORKOUTS BE THE MERE PRESENCE OF OTHER PEOPLE IN SPORTSWEAR?

Training with others – making it a social experience as much as chore or something performance-driven – is a big motivating factor, says Dr Alex J Benson from the University of Western Ontario in Canada. A psychologist and kinesiologist, his work looks at group dynamics in sport and beyond, including the benefits of group exercise.

"Group exercise can be an effective lever to help motivate, sustain and promote enjoyable physical activity," Benson says. "However, not all forms of group exercise are created equal and it's important to consider which group environments people will benefit from the most."

DO GROUP WORKOUTS MAKE US EXERCISE HARDER?

Stationary bike classes are one type of group workout found to increase people's threshold for exercise. Researchers at Kansas State University found that women who exercised with a teammate on stationary bikes increased their workout time and intensity by as much as 200 per cent. This is especially true if you exercise with someone you perceive to be better than you.

"There are motivational gains under certain circumstances, such as the Köhler effect," says Benson. "This is where less-capable individuals expend more effort to keep up with more-capable members. Also, research on running groups has shown that people can, to some extent, outsource their self-regulation to the group, such that the same intensity of exercise feels easier in a group."

Unsurprisingly, when we find exercise easier and more enjoyable, we also do it more often. Researchers have found that group exercise can be habit-forming with the buddy approach helping people to stay motivated over time. For example, when people commit to weight loss programmes with friends, they're more likely to stick to them than when they try to shift weight by themselves. →

BELOW The sociability element of Parkrun events has helped them spread to more than 20 countries

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ABOVE Exercising alongside people of a similar ability, or even slightly higher ability, might help you push yourself further

→ One of Benson's studies found that when people have a greater sense of 'groupness' in an exercise class or setting, they're more likely to have enjoyed it and pushed themselves harder. Benson puts it down to people having "a sense of shared interdependence, interaction with one another, and identifying as a member of the collective."

WHAT EFFECT DOES THE CLASS INSTRUCTOR HAVE?

Benson says that a workout instructor can help create this sense of togetherness. "An instructor's ability to create a sense of a shared experience can help satisfy some of our basic psychological needs, such as relatedness, autonomy and competence."

It might explain why certain Peloton instructors have millions of followers across social media or why Joe Wicks was able to motivate millions of people to workout from home to his live YouTube classes during the COVID-19 lockdowns.

IS IT ALWAYS BETTER TO EXERCISE IN A GROUP?

Exercise is a very subjective thing. There are plenty of people who prefer to sweat in solitude and only want to compete against themselves. There are also others that feel intimidated by group classes, especially if they're inexperienced and entering a more advanced class.

But most of the available research suggests that when you workout with people in your demographic and at your level, with shared goals and a shared mentality, you're more likely to enjoy yourself.

A 2017 study from the University of New England found that compared to people exercising alone, those in a group class reported higher stress-reduction, plus better physical, mental and emotional quality of life.

"One of the most challenging aspects of exercise for many (and why many interventions fail) is adherence over the long-term," says Benson. "As we're social animals and have a fundamental desire to connect and belong, group-based exercise interventions can help sustain adherence when people develop social connections with others."

by **IAN TAYLOR**

Ian is a freelance science writer and has written for BBC Science Focus, Men's Health *and* Askmen.com.

ANALYSIS

TECH-FREE BREAKS: A NEW WAY TO BEAT BURNOUT?

'Unplugging' holidays promise to improve your wellbeing, but there's little science behind them

Have you ever 'unplugged'? Also known as a 'digital detox' or 'media refusal', the term describes the growing trend to spend a good amount of time away from social media, smartphones and computers in an effort to reduce stress and improve wellbeing.

There's even an annual 'National Day of Unplugging' on the first Friday in March. It's intended to encourage people to unplug, unwind and do something other than use electronic devices and social media.

More recently, unplugging holidays have been popping up around the UK – getaways that aim to help city dwellers escape the digital grind. Essentially a luxury version of camping, these cabin-in-the-woods-type escapes variously involve locking phones and laptops in boxes for the duration of your stay or even living completely off-grid.

Studies have found that a sense of addiction to being online is a common reason for wanting to 'unplug' like this. But do digital detoxes really help improve people's mental health, and reduce stress and burnout?

The evidence so far is mixed.

Concern around the negative impacts of computers, smartphones and social media has been rising ever since they began to become ubiquitous. It has become so great that even the tech professionals in Silicon Valley who created social media are disconnecting (and even inventing new technologies to help them do it).

Many studies have looked at the effects of smartphones, computers, social media and the internet on us. Research has shown that checking email less frequently can reduce stress, and studies have linked Facebook use with lower wellbeing. The constant notifications and updates associated with smartphone use, in particular, have raised concerns over people's health, especially as they can disturb sleep patterns.

In fact, according to Karla Klein Murdock, professor of cognitive and behavioural science at Washington and Lee University in the US, studies have shown that just the presence of a smartphone can have a detrimental psychological effect – you don't even have to use it.

There's also the question of what we lose by spending so much time on digital devices. The results from one recent study suggest we underestimate the enjoyment we get from simply sitting and thinking.

Given all this, does unplugging help? When it comes to evidence for the benefits of abstaining from social

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"Studies have found that a sense of addiction to being online is a common reason for wanting to 'unplug'"

media and smartphones, the picture is not clear. One recent study, for example, found that taking a break from social media had no measurable positive effect on wellbeing.

Dr Jeffrey Lambert, a lecturer in health and exercise psychology at the University of Bath, says he hears terms like unplugging and digital detox being used more and more, but often they mean different things.

"When you start digging into the detail of studies, you see that researchers are using different terminology or defining social media use or technology use in different ways," he says. "There's a lot of debate around what we even mean by social media."

But there is some evidence that taking technology breaks, especially breaks from social media, could have positive impacts.

ABOVE There is some evidence to suggest that taking a break from using your devices can have a positive effect on your wellbeing

In a study published in 2022, Lambert and his colleagues looked at the effects of taking a week-long break from Facebook (now Meta), Instagram, Twitter (now X) and TikTok, and found a favourable effect on wellbeing, depression and anxiety compared to a control group who continued with their normal social media use.

Several other studies have illustrated the psychological benefits of unplugging, adds Klein Murdock. In one, participants who abstained from social media use for a week were found to have higher mental wellbeing and social connectedness and lower 'fear of missing out'.

Elsewhere, a recent meta-study by University College London researchers reviewing a selection of previously published studies found some evidence that higher social media use is related to poorer mental →

ABOVE Better quality studies on a wider range of people are needed before we can say for certain whether 'unplugging' has any real benefit

→ wellbeing. It also concluded that there is some evidence that interventions in social media use are effective in improving people's mental wellbeing, especially for those with depression and when used in conjunction with therapy-based interventions.

"They found that, generally, coming off social media, or taking a break from it, does seem to lead, overall, to better wellbeing," says Lambert.

The big caveat, he adds, is that studies in the area tend to have quite poor quality and also use university student participants rather than people with diagnosed levels of depression or anxiety.

Of course, the unplugging holiday trend also involves spending time in nature, and there's significant evidence that this leads to an improved wellbeing and better mental health. One study published in 2018 found a link between higher mobile phone use and a lower sense of connection to nature.

"Since both of these qualities are linked with lower wellbeing, there may be additional benefits to unplugging if you spend time in nature," says Klein Murdock.

Ultimately, far more research is needed to unravel the pros and cons of smartphones and social media, and their effects on us. After all, studies have also shown many people feel they get many positives from using them, notes Lambert, such as higher feelings of social capital or life satisfaction.

Experts have also pointed out the historic tendency for widespread concerns and even panic to emerge around new technologies we now consider mundane, from novels and household radios to horror films.

"Just like everything in life, it's a nuanced issue," says Lambert. For now, he advises people simply try out a range of different approaches to see which ones work for them. "I think a lot of the answers are sometimes kind of within us anyway, in terms of what we think might help us."

by **JOCELYN TIMPERLY** *(@jloistf)*

Jocelyn is a freelance climate and science journalist.

COMMENT

20MPH SPEED LIMITS: GOING SLOWER SAVES LIVES IN CITIES

Opposition to reduced traffic speeds may be a vote winner for politicians, but only in the short term

Since the Uxbridge and South Ruislip by-election at the end of July, low emission zones and 20mph speed restrictions, have been in the limelight. So much so that Rishi Sunak, the prime minister, declared that he is on the side of the motorist and called for a review of such schemes.

In any review, scientific evidence should play a prominent role in decisions about future policy, and although the politics of the issue are bound to stand out in strong relief, the scientific arguments also deserve an airing.

One very important part of evidence in the debate regarding traffic speed and road safety is that slower traffic saves lives. A recent study, funded by the National Institute for Health and Care Research, and carried out in the cities of Edinburgh and Belfast, found as much.

In Edinburgh, restricting the city's speed limits to 20mph reduced road deaths by almost a quarter and serious injuries by a third.

Road accident rates across the city fell without any extra traffic-calming measures or police patrols being put in place. The scheme was highly cost-effective and the relatively modest cost of replacing speed limit signs not only improved road safety, but also enhanced the quality of life for residents.

Prior to the new restrictions, 45 out of 100 cars in Edinburgh travelled faster than 25mph; one year later, this figure had dropped to 31.

The researchers behind the study observed that the number of collisions in one year fell by 40 per cent to 367, and there were 409 fewer casualties – a drop of 39 per cent. A breakdown of the casualty figures reveals that fatalities dropped by 23 per cent and serious injuries fell by 33 per cent.

The research team members were from the Universities of Edinburgh, Cambridge, East Anglia, St Andrews, Bristol and Queen's University Belfast. They also collaborated with the walking and cycling charity Sustrans. The researchers worked with local and national traffic authorities to gauge the effectiveness of the 20mph restrictions introduced by the City of Edinburgh Council in 2016. The new limits applied in 80 per cent of Edinburgh's streets.

The main objective of the study was to evaluate and understand the processes and effects of developing and implementing 20mph speed limits in Edinburgh and Belfast. An additional objective was to investigate the political and policy factors that led to the decision to introduce the new

GETTY IMAGES X2

"The year after implementation, the number of people who were supportive of the speed limits increased"

speed limits. The study involved researchers interviewing residents to assess the overall impact. They also examined official records and data, and studied how the decision was reached and how the new regulations were enforced.

As well as the previously mentioned reductions in road deaths and injuries, the study found that reducing traffic speed also helped to create better-quality environments. The researchers reached this conclusion by using a metric known as 'liveability', which includes various measures of safety, health, sustainability, transport, amenities and living standards. They found that liveability improved in both cities after the introduction of speed restrictions.

But the thing that may be of particular importance for politicians positioning themselves in this debate is that the year after implementation, the number of people who were supportive of the speed limits increased, as did their willingness to obey the limits. The increase in support suggests that the whole idea of speed restrictions is far less contentious than many politicians suppose.

The Belfast scheme, which was restricted to city centre streets, led to a two-per-cent drop in casualties and collisions. These results reflect the scheme's narrower reach, and the fact that it was implemented in an area where traffic speeds were already low prior to the trial – on average less than 20mph.

This was a mixed-methods study that comprised an outcome, process, policy and economic evaluation of the implementation in the two cities.

The City of Edinburgh Council expected there would be push back, and there were some vociferous critics early on. But these were from organised pro-motorist pressure groups, not the population as a whole. Taxi drivers didn't welcome the trial at first, and neither did local bus companies. In the end, however, there was little outright opposition. There was also some opposition in Belfast, mostly from commercial and delivery drivers, but, again, it didn't amount to much either.

The findings suggest that the pre-implementation period was particularly important. Appropriate publicity and information helped frame public and political attitudes.

The scale of implementation in the two cities had a bearing on the impacts. The city-wide approach adopted by Edinburgh was effective in reducing speeds and positively affected a range of public health outcomes. The narrower city-centre approach in Belfast (where speeds were already low) was less effective. Nevertheless, the main outcome of these two schemes was a reduction in road casualties at all levels of severity.

It is to be hoped that, as the debate around 20mph speed limits proceeds, the participants don't forget what we already know, what the data show, and the public health importance of reduced traffic speed and its consequences. SF

by **PROF MICHAEL P KELLY**
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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

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NEW TECH

IDEAS WE LIKE

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We give Google's Pixel Fold phone a workout on **p40**

+37 PER CENT

Over 37 per cent of the UK market spends over £1,000 on their smartphone (Source: *The Guardian*)

27,600,000 SMARTPHONES

The number of foldable smartphones expected to be sold by 2025 (Source: International Data Corporation's Worldwide Tracker)

REVIEW

Google Pixel Fold: The phone that's learning to walk before it runs

The Google Pixel Fold isn't perfect, but it succeeds in showing us that the search giant is going to be a serious competitor in the folding smartphone market

They may be incredibly impressive from a technical standpoint, but, personally, I'm unconvinced by folding smartphones. After the five minutes it took for their novelty to wear off, my time with Samsung's Z Fold smartphones left me questioning their point in the world,

So my hopes weren't exactly high when I got my hands on the Google Pixel Fold. Google's first attempt at a folding smartphone is glitchy, has a tendency to get hot from basic tasks and will cost you a whopping £1,749.

And yet, despite its obvious problems, the Google Pixel Fold is the first folding device to make me genuinely excited about the idea of having a smartphone-tablet hybrid in my pocket. I spent some time using Google's first foldable phone to find out the good, the bad and the ugly that it had to offer.

The Pixel Fold has cameras on each of its main surfaces

TWO BECOME ONE

Like the foldable phones that have come before it, the Google Pixel Fold looks like two smartphones that have been slapped together and linked with a hinge. While this does make for a bulky and somewhat heavy device in your pocket, Google has kept things stylish for when you need to whip it out.

A stainless-steel hinge and frame surround the device and their brushed-metal finish feels smooth to the touch.

While the front smartphone display feels premium, the inside tablet display seems rather flimsy, as if it would snap if you gave it an aggressive tap. But despite these obvious quirks, overall the Pixel Fold is clearly built to the standards of a phone with a price tag approaching £2,000.

A MULTI-SCREEN SET-UP

The Pixel Fold's smartphone display is the one you use most of the time and Google has made using it a good experience. It's a similar shape and size to the average smartphone display, but being a foldable, its the tablet display inside that counts.

"WHILE THE FRONT SMARTPHONE DISPLAY FEELS PREMIUM, THE INSIDE TABLET DISPLAY SEEMS RATHER FLIMSY"

Prise the Pixel Fold open and you find its 7.6in display. It's surrounded by a black bezel that isn't actually that noticeable. What is hard to turn a blind eye to, however, is the crease. This is present on all folding devices, but it's especially noticeable here.

Run your finger across the tablet display and it's met with an unmistakeable dip in the middle, one that remains hard to ignore even when you're reading or watching media.

The crease isn't the Pixel Fold's only physical issue. The first few times you unfold the handset are accompanied

Certain apps are optimised to make use of the larger screen or to mimic a dual-display set-up

by a deep fear of breaking your new and expensive device. It's a concern that subsides quickly, but even with the knowledge that Google has tested the Pixel Fold to ensure it can survive being unfolded 200,000 times, it can still feel somewhat fragile.

Certain apps and websites are formatted to make the most of the larger screen in the Pixel Fold's unfolded tablet format. News apps like BBC News and *The Guardian* offer a larger, more book-like approach to reading, and the same goes for most streaming platforms, such as YouTube and Netflix.

Certain apps use both screens to mimic a wider desktop display. WhatsApp, for example, shows your current chat on the right and your other conversations on the left – a design choice followed by Outlook, Messenger and other similar messaging apps.

But there are other apps that aren't optimised for this experience. In the tablet configuration, Reddit has two large black bars on either side, as does Instagram, TikTok, Facebook and even Fitbit (a Google-owned company).

Where the tablet mode really thrives, though is in its ability to multi-task. Two apps can be open at once, allowing you to write a shopping list while checking a receipt or watch a show while messaging a friend – similar to how you can when using two computer monitors.

The trouble is, by making the front display so similar to an actual smartphone, Google has made it less important to open the Pixel Fold to its tablet mode. As such, I rarely used its 'full-size' unfolded display, unless watching a show or reading articles.

FIRST TRY AT A FIRST IMPRESSION

This is Google's first attempt at a folding smartphone and it shows. The touchscreen for the camera works inconsistently; apps don't always open properly and can be glitchy when they do; and when you're folding or unfolding the phone, the content you're viewing can end up being displayed on the wrong screen.

What's more, the Pixel Fold has a has a tendency to get hot, even when performing quite minor tasks. Scroll through X (aka Twitter) for a few minutes and you can feel it warming up; give it a more rigorous task and the device works up a serious sweat.

ON CAMERA

Using a camera on a folding smartphone is always a strange experience. With a lens on the front and multiple lenses on the back of the folded smartphone configuration, and another in the middle of the unfolded tablet configuration, you have plenty of choice and solid performance across all the options. The back lenses get the most use and are able to zoom and produce clear shots with great colour retention.

Is the Pixel Fold up there with the best camera phones? Not quite, which is a shame considering the price, but it isn't far off and provides versatility as well as enough functionality for most users.

While the front smartphone and tablet cameras are lower quality, the device's folding ability means the better lenses on the back of the smartphone configuration can be used for selfies.

VERDICT

The Pixel Fold is flawed. It's glitchy, heats up in use and costs an arm and a leg. But it is Google's first attempt at a folding smartphone. Considering Samsung, the leading light in folding smartphones, is now on its fifth device, Google is looking like it could be a force to be reckoned with by offering a surprisingly strong debut model.

For now, the high price and unstable software makes the Pixel Fold difficult to recommend. But, with some work to iron out the creases, it might soon become harder to choose between the folding phones offered by Samsung and Google.

RATING

★★★★★

PROS

- Stylish build and design
- Impressive battery life
- Snappy performance
- Apps tailored to folding display work great
- Great front display

CONS

- Gets hot frequently
- Lots of glitches
- High price tag
- Bulky and heavy

INTERVIEW

AI is helping scammers try to trick you. Here's how you can stop them

Alex Hughes spoke to **Oli Buckley**, a professor of cyber security at the University of East Anglia, about the rise of deepfake scams and how to avoid falling for them

WHAT IS A DEEPFAKE?

A deepfake is something that uses an artificial intelligence (AI) algorithm to create content that looks or sounds realistic. So a video or even just audio.

The algorithms need very little training data and can create something that's quite convincing with a standard laptop that anyone could buy. Deepfakes made headlines and gained prominence, on the video side of things, by taking an actor's face and putting it on another person's body.

As with most evolutions in technology, this took a seedy route to begin with: actors' faces were put into porn. But sitting alongside that is this idea of an audio deepfake as well, where you can use AI to mimic someone's voice to a high standard with very little effort and data.

DOES A SCAMMER NEED A LOT OF VIDEO OR AUDIO DATA TO MAKE A DEEPFAKE?

[Deepfakes are] mostly based on data that's out there on the web, so celebrities are the easiest to replicate. With a movie or a podcast you could create something quite realistic.

As we all live our lives online now, you can get data about someone quite easily. One of my students could download one of my lectures and that's more than enough content to recreate my voice.

A couple of companies report that you can create a convincing deepfake with about 3-10 seconds of audio, so it's not loads of stuff that you need to create something that's convincing.

But if we step beyond just the technical accuracy, and a scammer starts to pull on someone's emotions and adds time pressure and makes things a little more stressful and chaotic, then even a fairly weak deepfake can be a lot more convincing to a potential scam victim.

HOW CAN DEEPFAKES BE USED IN THE CONTEXT OF SCAMS?

Being able to make people do or say whatever you want is quite a powerful ability for scammers. We've seen a rise in the sort of scams where someone will receive a phone call, or even a video call, from what appears to be a loved one saying that they're in trouble – that they've been in a car accident or that they've been kidnapped – and that they need money urgently.

These deepfakes are pulled from data that's available on the internet. They don't need to be 100-per-cent accurate as the scam relies on fear and desperation, because when you panic, you overlook inconsistencies.

"ANYONE COULD DOWNLOAD THE SOFTWARE AND MAKE A CONVINCING DEEPFAKE EASILY"

HOW CAN PEOPLE BEST PREPARE FOR THESE SORTS OF DEEPFAKE SCAMS?

It's easy to be critical when it isn't happening to you, but it's hard when it is and you're caught up in the moment. Does it sound like your loved one? Is it the sort of thing they would say? These are the questions to consider.

There are pieces of software that you can use to detect if you're dealing with a deepfake, but the chances of having one of those to hand are pretty slim. If you receive a call from a loved one that you're not expecting, call them back or text them to check where they are. Consider the reality of the situation and proceed from there.

CAN YOU LOWER YOUR RISK OF BEING TARGETED BY THESE TYPES OF SCAMS?

We all live quite publicly now, particularly because COVID created this sense of online community that grew as we were physically separated from each other.

A shift towards living some of our lives online and maintaining digital relationships through online personas means there's plenty of photos, videos and audio of us all online.

You could completely erase yourself online and remove your digital footprint, but that's a big ask. It's more about people being objective when they do come up against a potential scam and understanding how likely the content of a deepfake really is.

IS IT DIFFICULT TO MAKE A DEEPFAKE OR CAN ANYONE DO IT?

Anyone could download the software and make a convincing deepfake easily. You need seconds rather than minutes or hours of data to create an audio fake and anyone with a bit of time and

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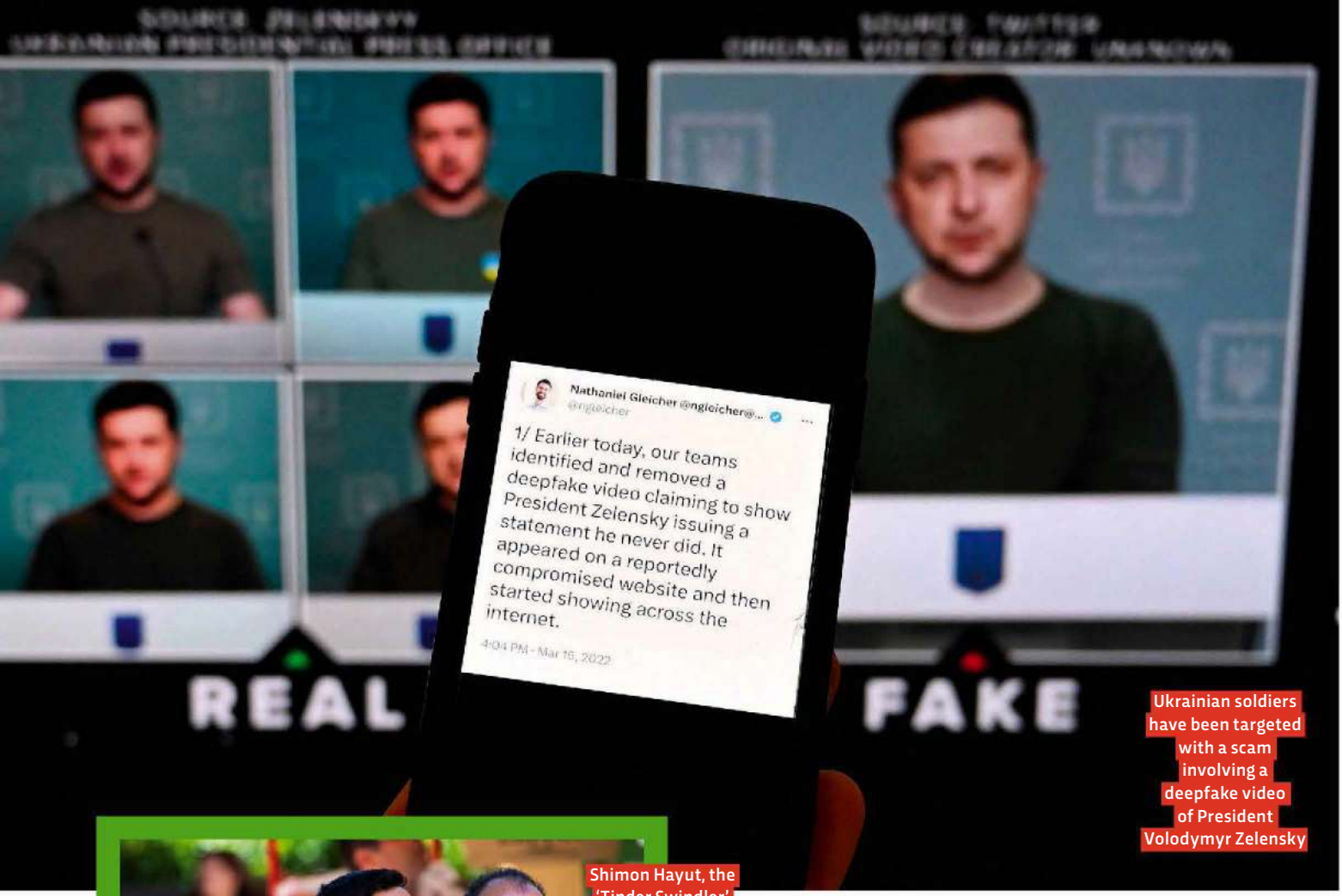
Nathaniel Gleicher @ngleicher@...
@ngleicher
1/ Earlier today, our teams identified and removed a deepfake video claiming to show President Zelensky issuing a statement he never did. It appeared on a reportedly compromised website and then started showing across the internet.
4:04 PM · Mar 16, 2022
REAL
FAKE

Ukrainian soldiers have been targeted with a scam involving a deepfake video of President Volodymyr Zelensky

Shimon Hayut, the 'Tinder Swindler' (centre), scammed people out of millions of dollars

access to YouTube could figure out how to do it.

It's both a benefit and a curse of the current AI boom. There's this amazing technology that would have seemed like science fiction not that long ago, but now anyone can use it. That's great, but there's always the flip side to how this technology is used.

ARE THERE ANY OTHER FORMS OF SCAMS THAT USE THIS SORT OF TECHNOLOGY THAT WE SHOULD BE ON THE LOOKOUT FOR?

There's an interesting idea called facial morphing. It takes images of two people and morphs them together to make a combination of them. If you stop the process midway through, then you get an image of a 'morph', which is a nonexistent person that resembles both people that were used to create it.

Morphs are already being used to create identification documents that look realistic. You could register a passport with a morph that could pass for either of the two people its based on, for example.

There was one case where a group of activists merged together a photo of a high-ranking politician with a member of their group to create a German passport that could have passed for both people.

SOME SCAMS DON'T PREY ON PEOPLE'S FEARS BUT ON THEIR HOPES INSTEAD. WHAT ABOUT THE RECENT NFT AND CRYPTOCURRENCY SCAMS?

We're all well aware of email scams where someone claims to have millions of dollars in a bank account, and that they need $500 to release it and will give you $1,000,000 if you help.

NFT and crypto scams are just a variation on that. They promise you a very big return on a very small investment. It's an offer that's too good to be true. It's more convincing and immersive now, but it's the same scam.

It still plays on the same innate human desires, whether it's to find a partner (the trick Shimon Hayut, the Tinder Swindler, used), or to make money, which is quite appealing to everyone right now. But it really comes down to questioning whether the offer sounds too good to be true, whether it's huge amounts of money being gifted to you or an NFT that could make you rich – either way it's unlikely.

Ideas we like...

Our pick of the month's smartest tech

...A net-zero-carbon shoe

Shoemaker Allbirds has been leading the way in sustainability for a while now, becoming increasingly eco-efficient and creating weirder designs as they go. The new M0.0NSHOT is not only hard to type, but also the world's first net-zero-carbon shoe. Its soft-knit upper is made with Merino wool from sheep reared on a carbon-negative farm, while the sole uses sugarcane-derived foam. The M0.0NSHOT is just one of the many products that are part of the brand's attempt to halve its carbon footprint by 2025.

Allbirds M0.0NSHOT
Allbirds.co.uk, £TBC

...A new 'old-fashioned' camera

Like vinyl records and folding phones, film cameras are another outdated technology we can't seem to leave behind. But that doesn't mean they can't be brought right up to date. The company Paper Shoot Camera is making digital cameras that are almost credit-card slim, but capable of producing images similar to those shot on film. Encased in stone paper, a durable material made from limestone and biodegradeable resin, the cameras have a low impact on the environment and come in a range of different designs.

Paper Shoot Camera
Papershootcamera.com, £131

...A TV in a briefcase

LG's new StanbyME Go looks like something ripped straight from the pages of a James Bond novel. A hard-shell briefcase opens up to reveal a smart touchscreen. It's equal parts utilitarian and outrageously over-the-top. With a wireless, built-in battery, which has a claimed three-hour life, this portable touchscreen can be used to watch a movie on a camping trip or stream TV shows at the beach. With a rotatable display, it can be used in landscape or portrait orientations, has adjustable light levels to deal with bright sunlight or dark, cloudy conditions, and can be controlled via a remote or 'hands-free' by voice command.

LG StanbyME GO,
lg.com, $999.99

...A remote-control crane

Operating a tower crane seems… well, terrifying. Climbing up to your seat takes roughly 15 minutes and isn't the most relaxing commute. But Radius Group, a lifting specialist company, has found an solution: a remote control for tower cranes. Using three displays on a desk in an office near the crane, the Skyline Cockpit – being introduced to the UK – opens the job of crane operator up to people who may not be comfortable with heights and makes it less lonely. It also offers real-time data on critical factors such as load weight and wind speed.

Skyline Cockpit
Radiusgroup.co.uk, £TBC

...A 'speaker' for deaf people

Accessibility tech has come on leaps and bounds in recent years. While it's often geared towards helping someone with their day-to-day tasks, some companies have branched out beyond that. Not Impossible Labs, a studio that uses technology to solve accessibility uses has designed a 'vest' that gives deaf people the ability to experience music in a new way. The Music: Not Impossible vest sends vibrations to the wearer's body with no latency, to simulate the vibrations of the music being played.

Music: Not Impossible
Notimpossible.com, £TBC

IDEAS WE DON'T LIKE...

...AI GETS MORE DYSTOPIAN

Despite his company OpenAI seemingly upending society with artificial intelligence, Sam Altman still has time for new dystopian projects. With his side company Tools For Humanity, Altman and business partner Alex Blania have created Worldcoin, a "privacy-preserving digital identity" and "digital currency received simply for being human". Sounds great, right? Except that getting your hands on some Worldcoin means getting biometrically verified by letting a metal orb (below) scan your face and eyes. Don't worry, it's not as creepy as it sounds; it's just so they can distinguish you from a robot in future.... okay, it is as creepy as it sounds.

Worldcoin
Worldcoin.org

...THE FRONT DOOR GETS MORE COMPLICATED

Tech companies have spent years trying to improve the front door. Thanks to cameras, smart locks and fingerprint scanners, the door has incrementally got more complicated, culminating in Masonite's newest product: the M-Pwr. It starts at a whopping $4,000 (just over £3,180) and can go up to $7,000 (almost £5,570), and that's just for the door – setup costs extra. The door includes a motion-activated light, a scanner to see if the door is closed when you're not there, a video doorbell, and a Yale smart lock. And the best part about having all this extra tech in your door? You need three separate apps to use it.

M-Pwr
masonite.com, from $4,000

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WHAT'S FOR DINNER?

Despite being a nutritious and sustainable food source, insects have yet to find their way onto our plates in a significant way. But these farms in Italy have found another, more palatable, way to use the protein in bugs: by turning it into animal feed

Words by
PROF ADAM HART
Photography by
LUIGI AVANTAGGIATO

LEFT Desert locusts (*Locusta gregaria*) bred for animal feed at the Italian Cricket Farm in Turin, Italy

When I was studying for my PhD back in the late 1990s, I read an article trumpeting the 'next big thing' in food. To be honest the next big thing didn't sound very appetising. Apparently, within the next decade or so, we would all be eating beetle burgers.

Entomophagy, eating insects, is common in many parts of the world. Given the ethical problems of farming livestock, insect farms were, the article boldly declared, the future of food.

Raised without welfare issues, insects are excellent at converting foodstuffs we can't use into protein that we can. What's more, they require far less space than livestock and contribute far less greenhouse gases than cattle.

But despite some clear advantages, a quarter of a century later diners in the developed world still aren't feasting on flies or baking with beetles.

The reason for this is obvious: while more than 1,000 species of insects are eaten around the world, most commonly in the tropics, Western societies generally don't eat 'bugs'. As the bushtucker trials of *I'm a Celebrity Get Me Out of Here* demonstrate, insect eating is an idea many people find disgusting.

Articles extolling the virtues of entomophagy continue to appear frequently in the media. And although the headlines often play on the perceived shock value, the authors are increasingly focussing on the ethical and climate-friendly aspects of insect farming.

Look beyond the 'Locusts for starters' headlines, and you'll soon see that insects are already well-placed to play a more important role in our food chain. Rather than us chowing down on fried locusts with a mealworm side-salad, we're developing ever-better ways to use insects: as food for the animals we prefer to eat.

ABOVE A sample of black soldier fly flour that gets incorporated into animal feed

LEFT A technician tends to the black soldier flies at the BEF Biosystem facility

A major star of this insect animal feed revolution is the black soldier fly (*Hermetia illucens*). Only around 16mm (approximately 0.5in) long, the adult flies resemble small solitary wasps. This mimicry is just evolutionary trickery however, because soldier flies have no sting and don't bite either.

A widespread species, it's their larvae (seen below right) that are key to the black soldier fly's importance. This is because black soldier fly larvae are 'non-selective' feeders, which is a polite way of saying that they'll eat almost anything. They thrive on all manner of food stuffs, from manure to animal and vegetable food waste – a characteristic that makes them excellent for waste disposal. This alone makes the black soldier fly useful to us, and that's before we even get to turning them into animal feed.

The waste-disposal process is called 'ento-remediation' and uses large chambers called bioconvertors (see page 54) that house large numbers of black soldier fly larvae. These larvae consume food and other organic waste and, in so doing, produce a soil-like organic residue that can be used as a rich fertiliser.

Inside the bioconverter, the larvae grow rapidly and 50 per cent or more of the weight they put on is protein. When they reach the pupal stage (the stage when they undergo metamorphosis to turn into an adult fly), they're at their nutritional peak. At this point, after they've already been useful converting waste into fertiliser, they can be harvested and used to feed animals.

Insect animal feed can replace conventional animal feeds that often rely on soybean meal. Soy has a high environmental cost because of the land and water required to grow it, and the resources needed to transport it.

Although much of the work on animal feed production has focussed on feeding livestock like pigs and chickens, black soldier flies are also being looked at as a food source for farmed fish. Currently, farmed fish food often consists in large part of fishmeal.

Fishmeal, also used to feed livestock, is made by drying and grinding fish. While this can be a good use of the parts of fish that we don't eat, and of bycatch that can't be returned to the sea, fishmeal production can encourage overfishing and depletion of vulnerable marine ecosystems. Being able to replace fishmeal with sustainably farmed insects could be a game changer for key aspects of marine conservation.

"SOME LOCUST SPECIES CAN BE BRED VERY SUCCESSFULLY AND ARE RELATIVELY EASY TO MAINTAIN"

FROM PET FOOD TO PEOPLE FOOD

Black soldier flies aren't the only species being farmed for animal feed, however. Some locust species can be bred very successfully and are relatively easy to maintain (such as the desert locusts on pages 48-49). Because insects are small and don't require much space, it's possible to keep them in tightly controlled conditions to optimise their growth and reproduction. →

BELOW LEFT The crickets used to make flour are checked

BELOW Black solder fly larvae

THIS PAGE An 'aviary' at the BugsLife farm in Perugia, Italy, is where the black soldier flies are kept to encourage them to reproduce

ABOVE After digesting the organic waste at the BEF Biosystem facility in Alessandria, Italy, the black soldier fly larvae are harvested and turned into animal feed. The digested organic waste is used for soil fertiliser

ABOVE RIGHT Organic waste is pumped into the bioconverters for the black soldier fly larvae to feed on

RIGHT Bioconverters at the BEF Biosystem facility in Alessandria, Italy

→ People that keep reptiles will likely be familiar with the house cricket (*Acheta domesticus*). This pale brown cricket is widely cultivated for feeding pets, but is being looked at as a potential source of protein for farm animals. These insects could also end up as a more direct part of our diet.

The Italian Cricket Farm, in Turin, Italy is investigating the potential for crickets to be processed into protein-rich 'insect flour' that can be incorporated into our food. Currently awaiting European Food Safety authorisation, it's exactly this sort of processing that may provide the culturally acceptable way for insects to enter our diet.

In fact, crickets can be rather good to eat without processing them into flour. I ran an insect-eating workshop at the Cheltenham Science Festival some years ago, and a local chef prepared a series of dishes for people to try. Brown crickets between sage leaves, deep-fried in a beer batter were a nibble that people tried first out of curiosity, but then came back to for seconds because they were so delicious.

The Italian Cricket Farm produces about 200,000 crickets a year, although this could be scaled up relatively easily. The efficiency of cricket production is impressive. Every 1kg (2.2lbs) of crickets requires just 1.7kg (3.7lbs) of feed to produce. When you compare that to the 10kg (22lbs) of feed required to produce 1kg of beef, the advantages become obvious.

What's more, the end product is incredibly nutritious, containing twice as much protein as beef, as well as a wide range of vitamins, minerals, fatty acids and other nutrients.

CHANGING TASTES AND ETHICS

As with any new and emerging ideas in food production, we need to be careful

"ANOTHER KEY ISSUE THAT NEEDS TO BE THOUGHT THROUGH IS THE ETHICS OF FARMING INSECTS"

ABOVE Piglets at the University of Bologna's animal house eating animal feed made with black soldier fly lavae

to think through any potential disadvantages. Clearly, what an animal eats can affect the quality of the meat it goes on to produce. Research into this is ongoing, but so far the data suggests that while insect feeds can affect the fatty acid content of meat, these changes are neither detrimental nor noticeable in terms of taste.

Another key issue that needs to be thought through, is the ethics of farming insects. The ethical concerns of animal use are complex and change as society and our scientific understanding changes. Over the past decades we've seen the introduction of far higher welfare standards for livestock farming than would have been thought necessary in the past, although many would argue that we still have a long way to go. These welfare advances have been focussed mainly on mammals, with a secondary focus on poultry, and far less focus on fish.

Insects, however, haven't really featured at all in our ethical discussion of animal use. Indeed, we've tended to think of insects as being incapable of feeling pain or suffering. But these views are beginning to shift. We're starting to learn more about the internal world of insects and discovering that they may be capable of feeling something we might identify as pain.

It's an emerging area of study, but in many cases the conclusions are that we might have to reconsider how we think about insects. That said, I think it's very unlikely indeed that we'll shift our view to such an extent that insects will ever be afforded the same welfare measures as 'conventional' livestock.

The greatest advantage of using insects for food, both directly and via animal feed, is environmental. Dredging oceans for fish meal or growing soy for protein feed are environmentally harmful, associated with high carbon costs and habitat loss or degradation.

On the other hand, rearing insects has the potential for a far lower environmental footprint. They take up less space, use less resource to produce more protein, can take advantage of human-produced waste and don't rely on exploiting or replacing habitat. Cranefly cakes and locust loaves might not be on your plate any time soon, but insect-reared pork, chicken and beef may well be. Perhaps that article 25 years ago was onto something, after all: insects might really be the future of food. **SF**

by **PROF ADAM HART**

Adam is an entomologist and Professor of Science Communication at the University of Gloucestershire. He's also a regular on BBC Radio 4 and BBC World Service.

BBC TWO

Watch Prof Brian Cox's new series *The Planets*, coming soon to BBC Two. Check *Radio Times* for details.

ILLUSTRATION: MAGIC TORCH

ANOTHER EARTH

A LITTLE UNDER TWO YEARS AGO, THE JAMES WEBB SPACE TELESCOPE CHANGED OUR HORIZONS, ENABLING US TO SEE MORE THAN EVER. BUT EVEN BEFORE WEBB LAUNCHED, ITS SUCCESSORS WERE BEING DEVELOPED AND THIS NEXT GENERATION OF SPACE OBSERVATORIES WILL HAVE LIFE ON OTHER PLANETS FIRMLY IN THEIR SIGHTS

by DR STUART CLARK

It has been just 18 months since an Ariane 5 rocket launched the James Webb Space Telescope into space. A collaboration between NASA, the European Space Agency (ESA) and the Canadian Space Agency, Webb has been widely touted as the successor to the Hubble Space Telescope. Indeed, it possesses observational capabilities that the astronomers who launched Hubble back in 1990 could only dream of.

Yet even as Webb shot into space on 25 December 2021, the astronomers watching it were already dreaming of the telescope that might succeed it. This was because they already knew the extent of Webb's potential: the size of its mirror, the wavelengths it could observe and the capabilities of its instruments.

"Even before it was launched, we were like, 'we need this other telescope that's going to be bigger," says Sarah Rugheimer, professor of astrophysics at York University, Toronto, Canada.

Big telescopes take a long time to develop – decades in most cases – and so planning starts early. "You don't just wait to see what happens with a telescope like Webb because you already know, theoretically, what some of its limitations will be," says Rugheimer.

In her field of astrobiology, Rugheimer is interested in looking for signs of life on planets orbiting stars other than our own. The best way to do this is to isolate the light from these exoplanets and analyse it for gases that may betray extraterrestrial metabolisms at work. Webb is able to do this for larger, gaseous planets, but those aren't the ones where we expect life to exist. Astronomers believe that rocky Earth-sized planets are much better targets. But as powerful as Webb is, it doesn't have the light-gathering ability to do this type of analysis for more than about five of these kinds of planets.

"When you're thinking about finding life in the Universe and you ask someone, 'Well, how many planets would you look at?' They're not gonna say five. They're gonna say hundreds or more," says Rugheimer.

So, when it comes to searching for life on exoplanets, Webb is a testing ground for a successor telescope that will be bigger and better.

NEW AND IMPROVED

In January 2023, Dr Mark Clampin, the director of NASA's astrophysics division, told a meeting of the American Astronomical Society that the successor to Webb would be called the Habitable Worlds Observatory (HWO).

Although it's still very early days in the HWO's design process – even the name is only a working title – a couple of things have already become clear about the project. HWO will be as large as Webb, but will observe at the same wavelengths as Hubble.

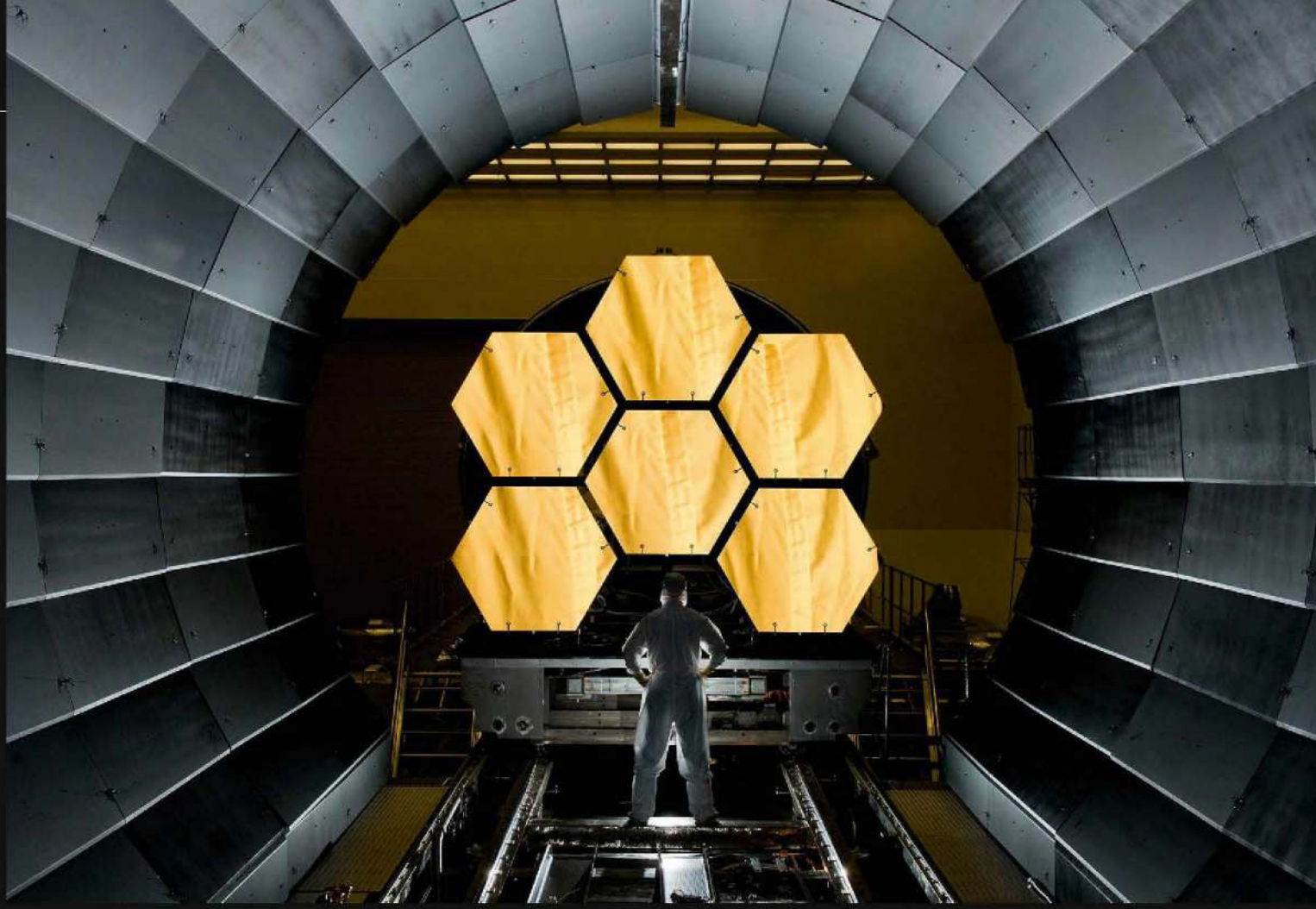
TOP Webb may have detected traces of water in the gas giant WASP-18b's atmosphere

ABOVE Exoplanet GJ 486 b (illustrated here), may have an atmosphere that contains water vapour

ABOVE RIGHT Six of the 18 mirrors that make up Webb's array

RIGHT Prof Sarah Rugheimer

NASA/ESO, SHUTTERSTOCK, BRET HARTMAN



"AS POWERFUL AS WEBB IS, IT DOESN'T HAVE THE LIGHT-GATHERING ABILITY TO DO THIS TYPE OF ANALYSIS"

This means that the HWO's mirror should be around 6m (19ft) in diameter and instead of infrared, it should work at optical and ultraviolet wavelengths. Like Webb, it will be situated at Lagrange Point 2 (L2), the gravitational sweet spot 1.5 million kilometres (approx 932,000 miles) from Earth. And, like Hubble, it will be designed for periodic upgrading, although these servicing missions will be undertaken by robotic spacecraft instead of astronauts.

The concept for this mission comes from an amalgamation of two others that NASA studied in the late 2010s. The first was called LUVOIR, the Large Ultraviolet, Optical and Infrared Surveyor. As the name suggests, it would cover a large range of wavelengths centred on visible light and be a general astrophysical observatory, as Webb and Hubble were. →

THE NEW GREAT OBSERVATORIES

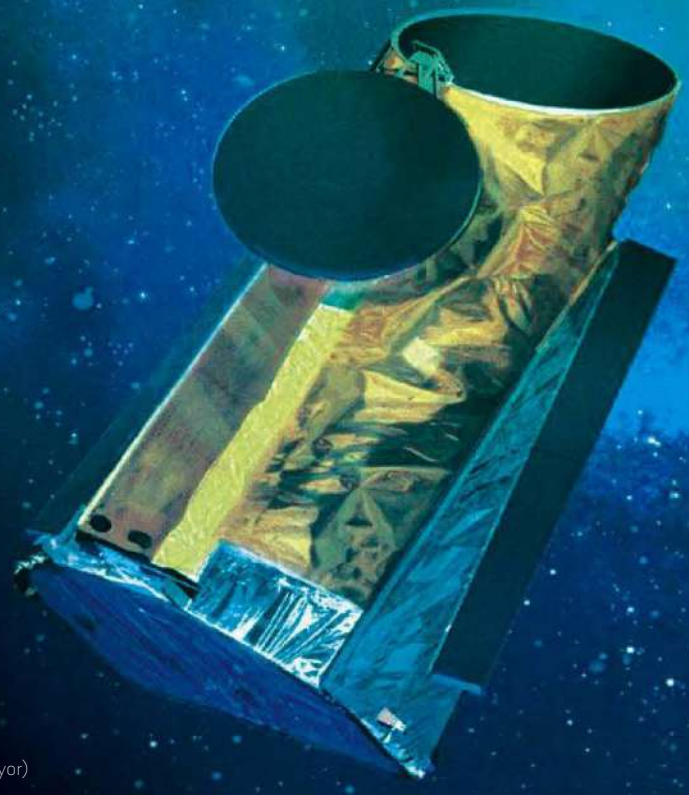
The 2020 Astronomy and Astrophysics Decadal Survey placed the development of a new suite of complementary space observatories at the top of the US's agenda for space-based astrophysics. In response to this recommendation, NASA began a dedicated technological development project for the new Great Observatories programme.

NASA's original great observatories were the Hubble Space Telescope, the Compton Gamma Ray Observatory, the Chandra X-ray Observatory and the Spitzer Space Telescope. Working both individually and collaboratively, these missions re-wrote the textbooks and revolutionised our understanding of the cosmos. But these spacecraft are ageing; only Hubble and Chandra are still functioning.

The New Great Observatories programme comprises three missions. The Habitable Worlds Observatory, which will work at ultraviolet, optical and infrared wavelengths. An X-ray observatory, Lynx, and the far-infrared mission called Origins complete the trio.

In Europe, other big missions, such as the X-ray mission NewAthena and the infrared mission LIFE, are being studied too. Together, if funded to completion, the European and American missions will provide complementary science.

When might we see the first of these great observatories launch? "The decadal survey said 2045, but on my more optimistic days, I would say that I think we can do it by the late 2030s. But that requires the stars – and funding – to align," says Prof Scott Gaudi, of The Ohio State University.



HabEx, (Habitable Exoplanet Imaging Mission) was a proposal that was combined with LUVOIR (Large Ultraviolet, Optical and Infrared Surveyor) to become the Habitable Worlds Observatory mission

SCOTT GAUDI ET AL, NASA/GSFC

"LIKE HUBBLE, HWO WILL BE DESIGNED FOR PERIODIC UPGRADING, ALTHOUGH THE SERVICING MISSIONS WILL BE UNDERTAKEN BY ROBOTIC SPACECRAFT"

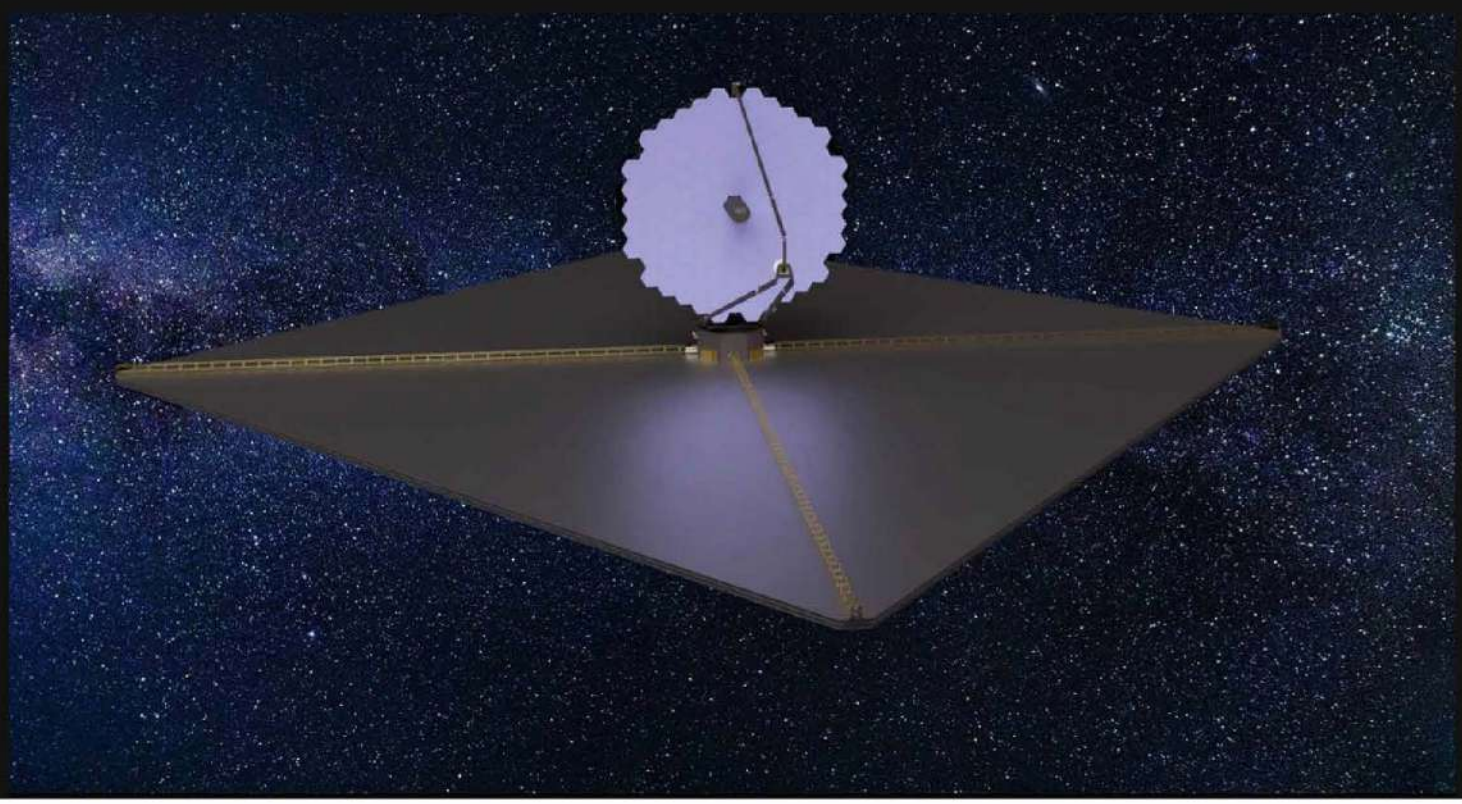
→ Two conceptual designs were developed for LUVOIR: one with an 8m-diameter (26ft) mirror and one with a 15m-diameter (49ft) mirror. Both designs would be made of hexagonal mirror segments like Webb.

The second concept that NASA investigated was the Habitable Exoplanet Imaging Mission (HabEx). This was envisaged to be a space telescope with a 4m-diameter (13ft) mirror. Although optimised for the investigation of exoplanet atmospheres, it could also extend many of the investigations that Hubble had pioneered.

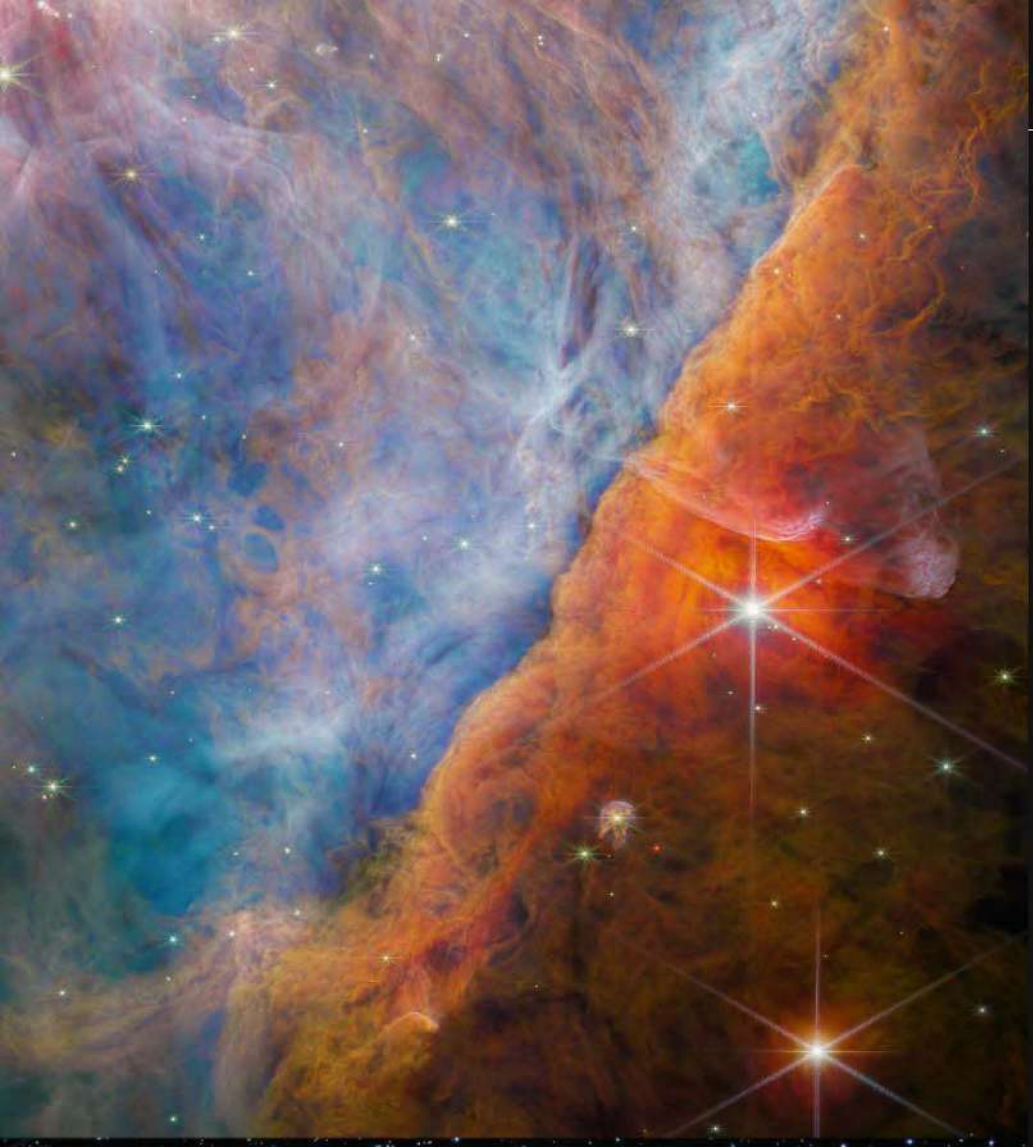
"HabEx was designed to be a somewhat more conservative mission [than LUVOIR] that could still address the main science goal of directly imaging and taking spectra of Earth-like planets around nearby Sun-like stars. It would also enable a broad range of other astronomy, the sort you could have done with a Hubble that had a larger aperture and modern technology instruments," says Scott Gaudi, the Thomas Jefferson Professor for Discovery and Space Exploration at The Ohio State University, who was part of the HabEx study.

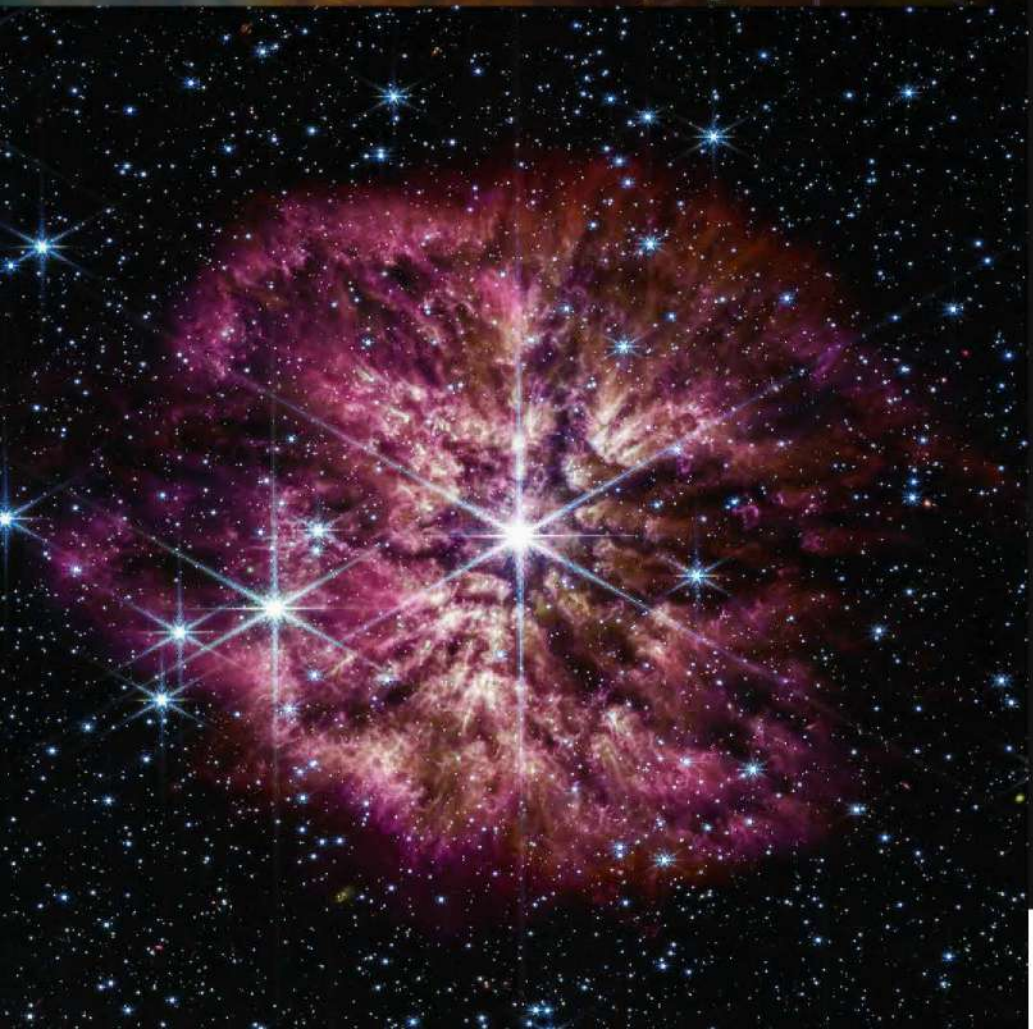
Both projects were submitted to the 2020 Astronomy and Astrophysics Decadal Survey, run by the National Academy of Sciences in the US, along with two other mission concepts: an X-ray telescope called Lynx, and a far-infrared telescope called Origins.

After due deliberation, the survey recommended NASA conduct a programme of technological development for five years to ready itself to build all of these missions (see 'The new great observatories'), with the caveat that LUVOIR and HabEx be merged into →



BELOW One design concept for the LUVOIR equipped the observatory with a 15m-diameter mirror





LEFT Thanks to Webb's capabilites, astronomers were able to detect a molecule of methyl cation in a protoplanetary disc in a star system within this image of Orion's Bar

BELOW LEFT Webb caught this image of the star Wolf-Rayet 124 (centre) in the process of casting off its outer layers prior to going supernova

→ a single mission with a 6m-diameter (19ft) telescope. This is the mission now called HWO that Clampin announced at the American Astronomical Society, and it will be the first mission to be worked on to completion of the technology development.

THE BREATH OF LIFE

Searching for life on other worlds is a dream long held by astronomers. Traditionally, it has relied on using radio telescopes to listen for signs of extraterrestrial communications. This, of course, assumes that the extraterrestrials are technologically advanced (but not too advanced), so that they're using radios.

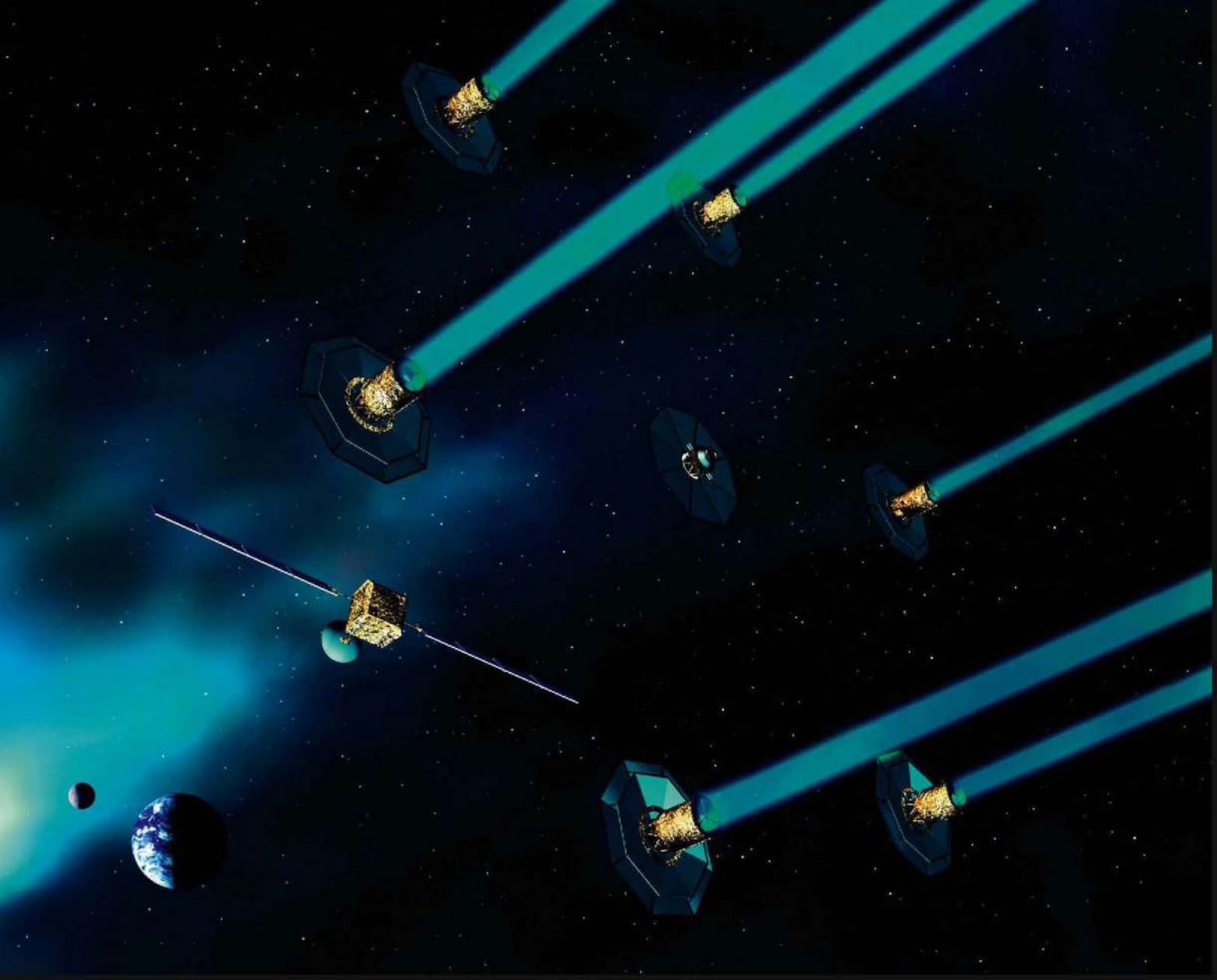
When searching for non-intelligent species, however, we've so far been restricted to our Solar System, and the spacecraft designed to scour the Martian landscape, or observe the moons of Jupiter and Saturn for signs of habitability or life.

The HWO would totally change that by opening up the search to planets beyond our Solar System, and by being sensitive to life at any stage of its evolution. The trick to doing this is the fact that all living things breathe. This means taking in one gas and expelling another. On Earth, that process forces our atmosphere out of 'chemical equilibrium' by placing more oxygen and methane in our atmosphere than would otherwise occur.

If life vanished from Earth tomorrow, the oxygen and methane the atmosphere contains would gradually be removed by chemical and geological processes.

So, to find a planet with an atmosphere that can't be explained solely by chemistry could be a sign that there are breathing lifeforms constantly replenishing the atmosphere with

NASA/ESA/CSA X2, ESA



ABOVE ESA's Darwin mission concept proposed using a flotilla of spacecraft to observe the atmospheres of exoplanets

molecules that don't otherwise coexist in nature. And the way to do that is to isolate the light from the target planet.

Light carries so much more information than just the brightness of a celestial object. Splitting light into its constituent wavelengths produces a rainbow-like spectrum that's intersected with a series of dark lines. These lines are produced by the different atoms and molecules that the light has passed through.

Each chemical absorbs a different pattern of wavelengths and so produces a different pattern of dark lines. It's the equivalent of a fingerprint, and allows astronomers to determine the chemical composition of a celestial object, no matter how far away that object happens to be.

"THE HABITABLE WORLDS OBSERVATORY WOULD TOTALLY CHANGE THAT BY OPENING THE SEARCH UP TO PLANETS BEYOND OUR SOLAR SYSTEM"

But collecting enough light from a planet is fiendishly difficult because the planet only reflects starlight, and its parent star is a billion times brighter.

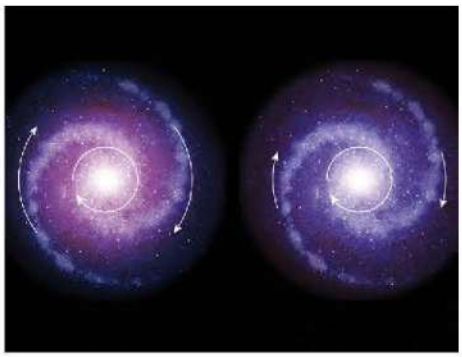
"The analogy that often gets used is that it's like trying to detect a firefly next to an industrial searchlight. The firefly and the searchlight are about 5m (16ft) away from each other, but are located in Los Angeles, while you're standing in New York City. That's the analogy; although, it's actually much worse than that if you go through numbers," says Gaudi.

What this means, in practice, is that some means of suppressing the star's light will be needed by the telescope in order for the planet to be seen. In HWO, a device called a coronagraph will be used to physically block the light from the central star, but it's a delicate operation that relies on extreme precision.

"Coronography is hard, especially at this level. It's one of the technology tent poles that we're dealing with right now, trying to advance it to the point where it needs to be for the Habitable Worlds Observatory," says Gaudi. →

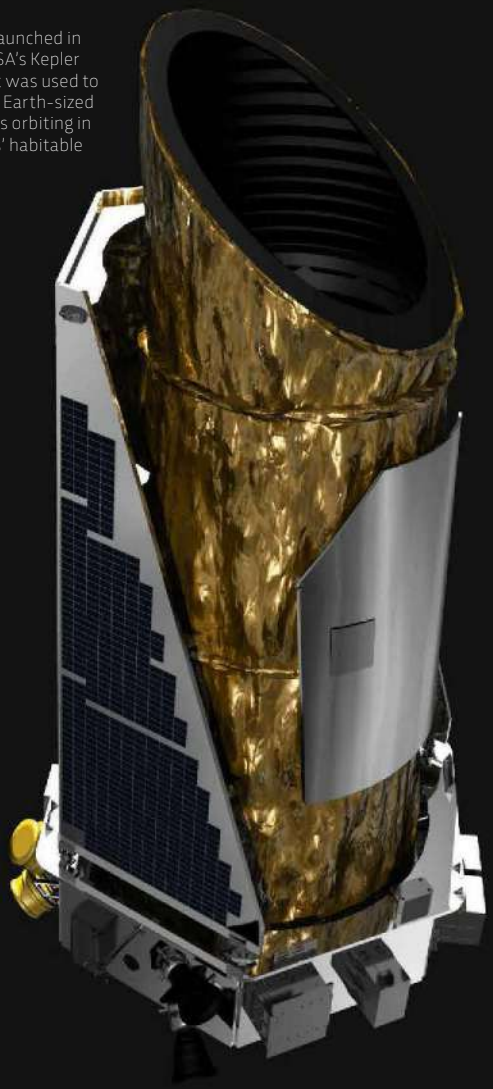
WHAT WILL THE HWO INVESTIGATE?

SIGNS OF LIFE ON PLANETS OUTSIDE OUR SOLAR SYSTEM AREN'T THE ONLY THINGS THE HABITABLE WORLDS OBSERVATORY WILL BE LOOKING FOR...



1. MOVEMENT
HWO will measure the movement of individual stars in galaxies beyond the Milky Way to allow astronomers to analyse the rotation of those galaxies. A galaxy's rotation is thought to be determined by the distribution of mysterious dark matter around it. These measurements will allow astronomers to investigate that distribution.

2. EXPANSION
HWO will observe Cepheid variable stars to allow astronomers to measure the expansion rate of the Universe with much greater accuracy. Astronomers have uncovered the 'Hubble tension', where the expansion rate determined by different methods don't match. These measurements will either help resolve the tension or confirm its reality.



RIGHT Launched in 2009, NASA's Kepler spacecraft was used to search for Earth-sized exoplanets orbiting in their stars' habitable zones

→ While NASA is betting on coronography, there are other ways to suppress the blinding starlight.

Rugheimer is involved in a project called the Large Interferometer For Exoplanets, or LIFE for short. Coordinated by the Swiss Federal Institute of Technology (ETH) in Zürich, LIFE could become a mission of its own.

Like HWO, LIFE is focused on investigating nearby planets to analyse their atmospheres for traces of life. Unlike HWO, it prioritises the infrared part of the spectrum and isn't a single telescope with a coronagraph. Instead, LIFE is a flotilla of space telescopes that would combine their light in such a way that a process called destructive interference would eliminate the glare from the star, leaving the much fainter reflected light from the planet to shine through.

It's a resurrection of an idea that ESA pioneered in the mid-1990s and studied for around a decade. Back then, the concept was called Darwin and would have consisted of three or four 4m (13ft) space telescopes and a central beam-combining spacecraft. As envisaged, Darwin would have been able to provide images that were 10-100 times more detailed than Webb.

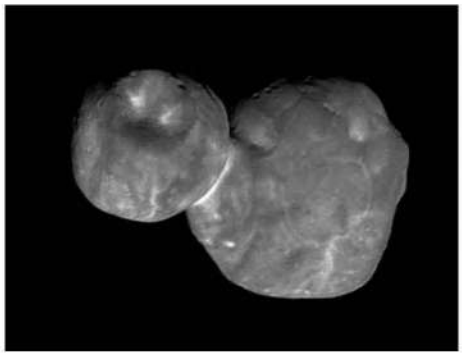
It was a technologically challenging and expensive mission, but ultimately it was shelved because, back then, we simply didn't know enough about exoplanets. Astronomers had no idea how many Earth-sized worlds there were or how close we might find them to the Solar System. Darwin was designed to, first, find the planets and, second, analyse their atmospheres. But in a worst-case scenario, Darwin could have discovered that Earth-like worlds are rare and so have no targets to investigate.

"I would say that was the main reason Darwin didn't move forward," says Rugheimer.

NASA X2, NASA/ESA/J NICHOLS, HUBBLE SPACE TELESCOPE, ESO/L CALCADA, NASA/JPL/SSI

3. AURORAE
HWO will observe aurorae on the outer planets of the Solar System to allow astronomers to investigate the magnetic influence of the Sun. The space between the planets is filled with magnetic fields and electrically charged particles from the Sun. These observations will allow astronomers to understand how planets interact with these components.

4. VOLCANISM
HWO will investigate cryovolcanoes on moons such as Europa and Enceladus to allow astronomers to investigate their interiors. Moons with volcanic eruptions of water and ice are thought to contain oceans. HWO's observations would allow astronomers to investigate the composition of these oceans without the need to a visit the moons.



5. OBJECTS
HWO will measure the objects in the Kuiper Belt, beyond the orbit of Neptune, to allow astronomers to calculate their size and density. The icy, rocky objects on the edge of our Solar System are 'leftovers' from the formation of the planets. Observations of them will allow astronomers to understand more about the formation of the Solar System.

"NASA'S KEPLER SPACE TELESCOPE HAS PERFORMED ITS EXOPLANET CENSUS AND SHOWN THAT PLANETS OUTNUMBER STARS IN THE GALAXY"

Now, around three decades later, things are very different. NASA's Kepler space telescope has performed its exoplanet census and shown that planets outnumber stars in the Galaxy. More than that, 20-50 per cent of stars are likely to have rocky planets similar in size to Earth located within their habitable zones – the orbital region where it's warm enough for liquid water to exist on the surface.

The LIFE concept emphasises the infrared part of the spectrum for two reasons. Firstly, the contrast between the star and the planet is 'only' a million to one, meaning that the star is a million times brighter than the planet. This is a thousand times better than the contrast in the visible region of the spectrum where the star outshines the planet by a billion times to one. So extracting the planet's signal from the glare from the star is easier at infrared wavelengths.

Secondly, a much higher amount of molecules interact with infrared than with visible light, so the analysis of the atmosphere can be more complete.

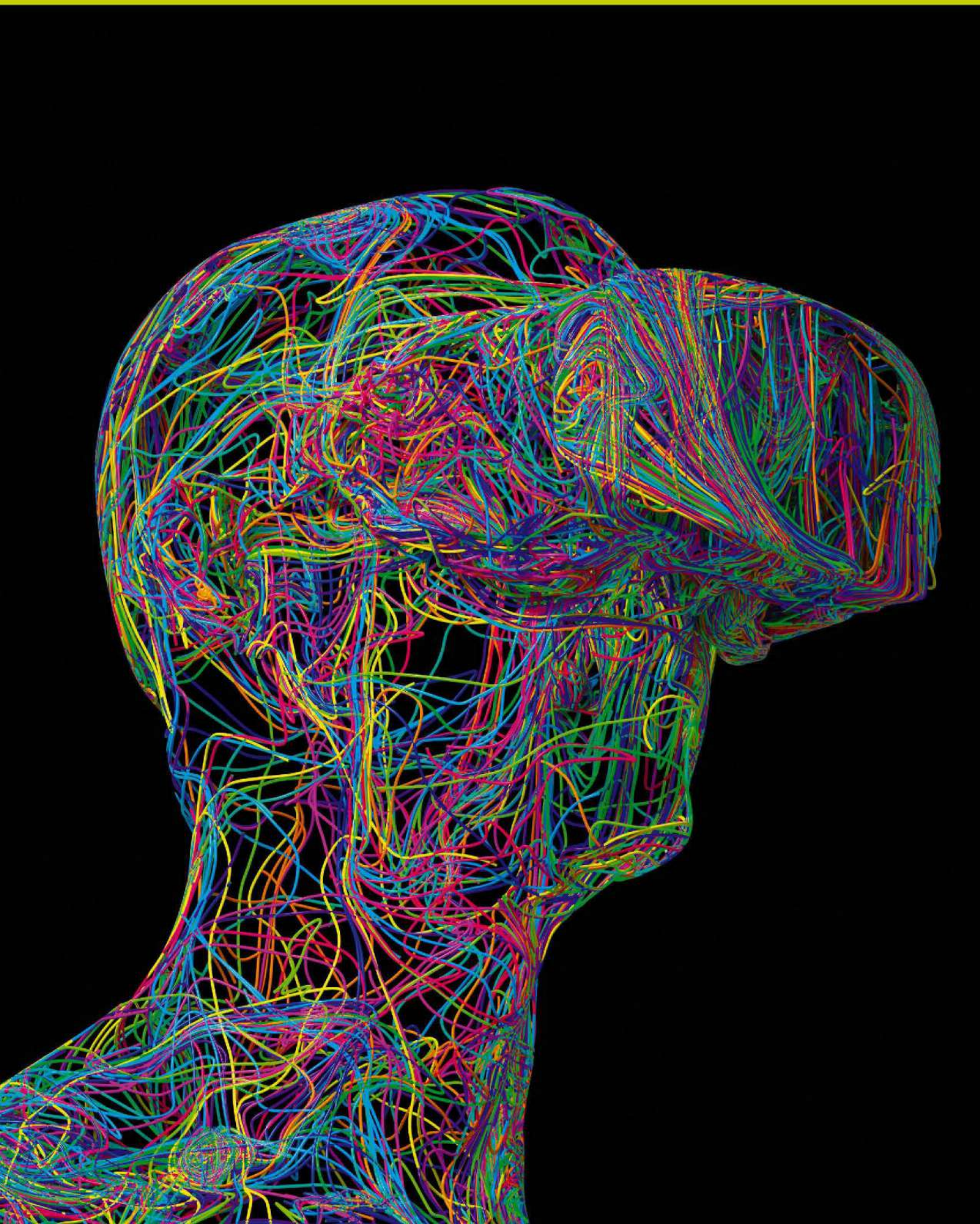
This is not to say that the visible is second-rate, however. Oxygen, water and carbon dioxide are all detectable at visible wavelengths and are all essential for showing whether there's life on the target world. The ultraviolet wavelength offered by HWO would also reveal the magnetic activity of the parent star. If those levels are high, it could jeopardise the habitability of the planet.

Another thing that we may be able to see at visible wavelengths is the reflection of the star's light from any oceans that might be present on the planet.

Of course, the ideal situation would be to have both HWO and LIFE. "If I had unlimited money, I would do both. We want all the wavelengths," says Rugheimer.

Whether astronomers get both remains to be seen. And beyond looking for life on other planets, there are a great number of other investigations that these observatories can also tackle (see 'What will the HWO investigate?'). So whatever Webb's successor looks like, it's certainly going to have a lot of work to do. **SF**

by **DR STUART CLARK** *(@DrStuClark)*
Stuart is a Fellow of the Royal Astronomical Society and the author of Beneath the Night: How the stars have shaped the history of humankind *(Faber).*



WARNING

Psychedelics, such as 'magic mushrooms' and LSD, are Class A drugs according to UK law. Anyone caught in possession of such substances can face up to seven years in prison, an unlimited fine, or both. Information and support for those affected by substance abuse can be found at bit.ly/drug_support

ALTERING REALITY... INSIDE AND OUT

Psychologists are exploring ways of treating mental health disorders by combining psychedelics and virtual reality

by DR DEAN BURNETT

How would you go about changing your reality? There are many options available to the modern human, with varying degrees of permanence and legality. But perhaps the simplest method is to find a place where reality is different to what you're used to, and go there.

I tried this option in November 2022, by attending the Wonderland International Psychedelics conference and exhibition in Miami.

As a Welsh neuroscientist from the Cardiff suburbs, with no involvement with/experience of class-A drugs, exploring an international conference dedicated to them in the heart of an humid US city was, to put it mildly, outside my usual comfort zone.

I was, admittedly, already aware of the ever increasing evidence for the enormous potential of psychedelics to treat multiple mental health conditions, hence I was keen to attend the event. What I wasn't aware of, however, was the industry that's built up around them as a result, which has lead to many people taking psychedelics in many intriguing (if sometimes baffling) directions.

One that caught my eye at Wonderland was by Enosis Therapeutics, who generously allowed me to experience their AnchoringVR set-up. The brainchild of researcher Agnieszka Sekula, at first glance it appeared to be a virtual reality (VR) simulation of a surprisingly pleasant and realistic moonlit beach environment.

The beach was sprinkled with floating star-like objects, which you could (via the relevant hand controls) pick up and speak into. Anything you said while holding the star would be recorded and saved for retrieval and replay later. Alternatively, you could throw these stars, and their associated →

ALAMY

→ audio logs, into the ever-burning campfire present in the scenario.

All very nice and relaxing sounding, but what does it have to do with psychedelics? Or mental health?

In a sense, everything. Because this is just one example of an interesting and unexpected new approach to treating mental health problems: combining psychedelics and virtual reality.

DIVERGENT PROPERTIES

Combining psychedelics and VR may seem like a strange notion, because, in many ways, psychedelics and VR couldn't be more different.

For one thing, psychedelics are, to put it mildly, 'old school'. You'd be forgiven for assuming that psychedelics had the biggest impact on our culture during the 'Psychedelic era' during the 1960s and 70s. But actually, humankind's enthusiasm for psychedelics goes back considerably further.

Psychedelics occur naturally in the wild. They can be found in mushrooms, cacti, leaves, stems and more, and for most of our history, humans survived by eating things that grew in the wild. As a consequence, humans have been consuming psychedelics for a very long time. Tribal rituals involving psychedelics took place as far back as 9,000 years ago. Ergo, humans have been taking psychedelics for literally thousands of years. It's why they're so heavily intertwined with rituals and traditions concerning spirituality, mysticism and religion.

None of this applies to VR, however, which is an entirely modern phenomenon. Granted, it has existed in some form since the 1970s, or possibly even the 1950s, but that's about it.

This is because VR can only exist in the context of modern technology. And as technology has improved, so has interest in VR and the possible applications of it.

Rather than spirituality and mysticism, VR has historically had more practical applications. NASA has used VR for training purposes for decades, as have various militaries. And it's constantly threatening to be the next big thing in video gaming.

So, psychedelics and VR have little in common. Unless you count the whole 'altering the reality we perceive' aspect. But even here, they go about it in radically different ways.

In a very oversimplified nutshell, psychedelics are biological molecules that interact with certain neuron receptors, leading

TOP Dr Dean Burnett at the Wonderland International Psychedelics conference

ABOVE Dean tries out the AnchoringVR experience while Agnieszka Sekula (centre) looks on

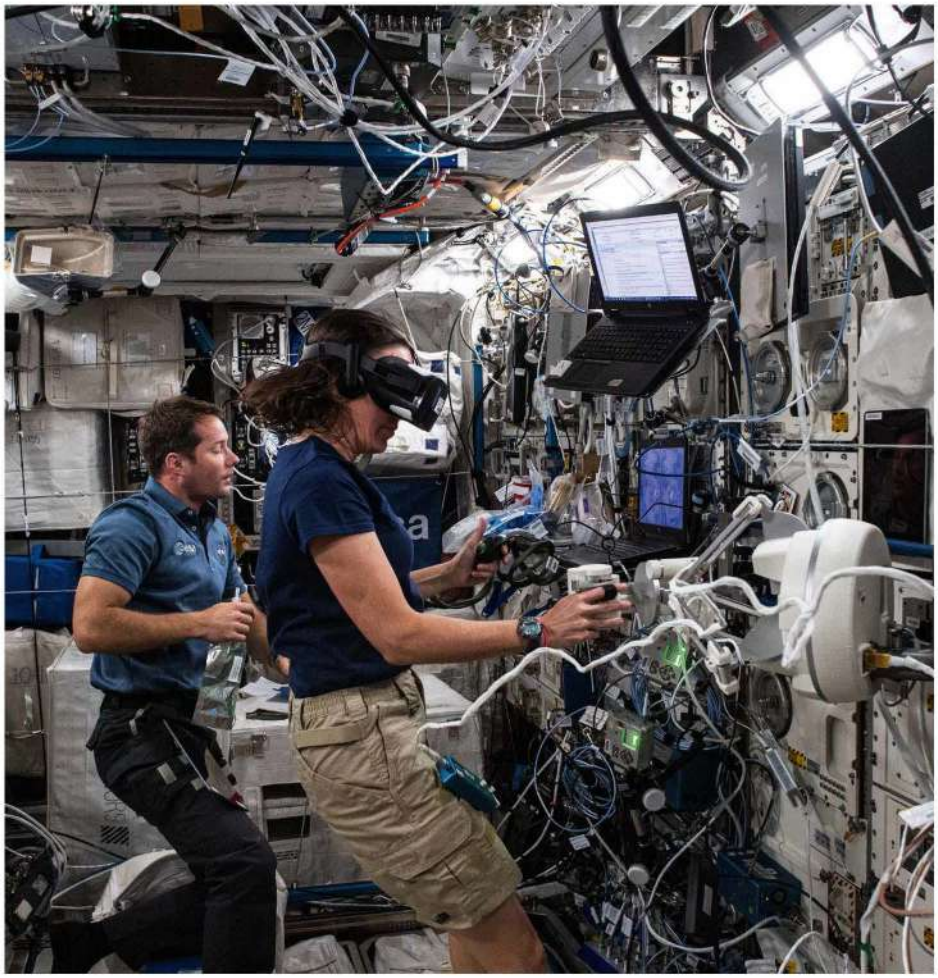
"VR, IN CONTRAST, LEAVES THE INNER WORKINGS OF YOUR BRAIN ALONE"

to suppression of the brain's default mode network, the underlying system that's seemingly crucial for your sense of 'self', for internal modes of cognition. Shutting this network down means your internal processes become mixed up, they overlap, and blur, and your ability to recognise where you are in time and space is compromised.

VR, in contrast, leaves the inner workings of your brain well alone. Instead, it blocks out the external sensory environment (to a greater or lesser extent) and substitutes it with a synthetic, technologically generated one.

While a less 'profound' experience than that provided by psychedelics, VR offers an alternative reality that's 100 per cent controllable, tailor-made to suit the situation. And if we eventually advance to a point where VR environments are indistinguishable from objective reality, while having none of the restrictions, not even the sky's the limit for what we could experience with it.

WONDERLAND MIAMI CONFERENCEX2, NASA, ALAMY



ABOVE NASA astronaut Megan McArthur taking part in an experiment in which she attempts to operate a robotic arm via VR controls

LEFT Certain species of mushrooms contain the psychoactive compound psilocybin that can induce psychedelic experiences

So, psychedelics and VR are both means of altering reality, but with radically different origins, histories, associations and mechanisms of action. However, contrary to what most people might assume due to the scaremongering surrounding them, the properties of both psychedelics and VR mean that they have significant scope to have a positive impact on mental health.

SPIRITUAL, TECHNOLOGICAL, MEDICINAL

While the 'recreational' aspects of a 'trip' are probably what most psychedelic enthusiasts are interested in, making the brain's internal workings more flexible, malleable and interconnected is how psychedelics can make it easier to tackle the unhelpful patterns of thought and connections that underlie mental health problems, which are often deeply ingrained.

This gives psychedelics the therapeutic potential that's increasingly hard to ignore. The existence of a three-day conference and exhibition dedicated to them is a stark demonstration of this. As is the recent move by a number of US cities to decriminalise the use of psychedelics for therapy research and, in the case of Australia, to legalise them for prescribed medicinal use.

It's quite a turnaround when you consider that, barely a decade ago, psychedelics were some of the most restricted drugs around, due to being a casualty of the War on Drugs.

Similarly, that modern screen-based technology could be beneficial for mental health may also seem counterintuitive. After all, aren't we constantly being warned about the damage screen time and smartphone use are doing to our mental wellbeing? →

ABOVE SoundSelf is a system that uses biofeedback that is claimed to generate a therapeutic psychedelic experience

BELOW Patients undergoing psychedelic therapy are typically guided through the treatment sessions with music or audio cues

→ While there is certainly a discussion (preferably an evidence-based one) to be had about such concerns, modern technology has been an increasingly common aspect of mental healthcare for some time now.

Technology that offers bio- or neuro-feedback allow a patient to observe the anomalous things occurring in their body and brain during an anxiety attack, giving them something more usefully 'concrete' to try and get under control.

We now have digital or online therapies, allowing patients in need to access help remotely via their devices, relieving pressure and demands on both patients and health services, such things are now recommended in official guidelines.

There's also avatar therapy, which creates a helpful and reassuring virtual 'source' for a patient's psychotic audio hallucinations.

All of these things, and many more, are increasingly common means of treating mental health problems, and all are 100 per cent dependent on modern technology.

Looked at this way, it's perhaps unsurprising that VR is also becoming an increasingly common therapeutic tool. From allowing 100 per cent controllable and beneficially gradual exposure to the triggers of phobias and post-traumatic stress disorders, to rehabilitating dementia patients via more regulated environments.

It now seems that psychedelics and VR do have something in common: they both seem to have great potential as therapeutic tools for mental health. And if they were combined, maybe they'd be even more effective.

STRANGE COMBINATIONS

As Agnieszka Sekula explained to me at the Wonderland conference, the Enosis AnchoringVR setup is intended for patients who are just completing a psychedelic-assisted therapy session.

This is where a patient takes a dose of psychedelics (usually psilocybin or MDMA) in the presence of a trained therapist. The psychedelic state allows for much greater cognitive flexibility and general positive emotion, increasing the impact of introspection, revelations, insights and so on. All of which can be very beneficial for mental health conditions and have lasting positive impacts.

But one concern is that the psychedelic state is temporary, and insights and progress acquired during it may not endure beyond it. After all, context is a big part of memory.

As Agnieszka explained, "The psychedelic experience is a multisensory, embodied, deeply immersive experience, which is difficult to put into words. Therefore, processing it through the method of talk therapy seems almost counterintuitive – and yet, this is the predominant approach to integration".

"Immersive (VR) environments allow us to exploit all the senses in therapeutic engagement, give patients an opportunity to express themselves in a multisensory fashion, but also, and perhaps

"We are a company focused on achieving the most efficient development of products that address significant unmet needs in CNS disorders and in rare diseases"
SEELOS THERAPEUTICS

SOUNDSELF, WONDERLAND MIAMI CONFERENCE GETTY IMAGES

ABOVE LEFT
Dean (far left) takes part in a panel at the Wonderland International Psychedelics conference

"WE NOW HAVE DIGITAL THERAPIES THAT ALLOW PATIENTS TO ACCESS HELP REMOTELY"

most importantly, they allow them to journey through their expressions, to explore, together with their therapist, the contents of their psyche"

The Enosis AnchoringVR set-up immerses the patient in the previously mentioned beach scenario as they're recovering from their 'trip', where they can use the calming multisensory interface to record their insights while they're still fresh in the patient's mind, and revisit them, in the same rich context, at the next session, thus better retaining and building on them.

It's a similar idea to the 'checkpoints' you often encounter in video games that let you save your progress, so you don't have to start all over again each time. This approach essentially provides the same thing for therapy, complete with the advanced graphics!

VR can also be useful at the start of psychedelic therapy. Because it's such a powerful intervention, psychedelic therapy must be carefully managed. This includes creating the right 'setting' to put patients in a suitably positive frame of mind, because psychedelics combined with a negative headspace lead to a 'bad trip' – not helpful for someone already dealing with poor mental health.

If the initial environment is important for psychedelic therapy, VR, offering a 100 per cent controllable environment, may well make things much easier for both patient and therapist. There are an increasing number of techniques incorporating VR and psychedelics, or altered consciousness, with increasingly interesting approaches.

Some may think this all a bit unlikely. After all, as good as it may be, modern VR is still readily identifiable as artificial. Could it really have such tangible effects on people?

Sure it can. After all, VR motion sickness is definitely a thing, revealing that, while we may consciously recognise VR as artificial, the subconscious processes that do most of the brain's heavy lifting are perfectly willing to accept it, certainly enough to immediately affect what's happening in the user's body.

Of course, it's still very early days for this intriguing combination of therapeutic interventions. There are still issues to be addressed, such as how psychedelics are very powerful therapeutic tools that need to be used carefully, under professional supervision. Or how effective VR requires much technological support and investment, in terms of both resources and expertise.

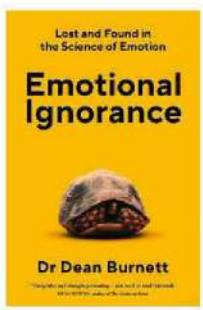
There are also those who contend that psychedelic therapy is sufficient in its own right, and including VR in the process is an unnecessary distraction.

Conversely, there are studies which suggest that a therapeutic psychedelic state can be induced via VR alone, removing the need for consumption of potent chemicals. Overall, though, psychedelics and VR represent an interesting, combined-therapy approach and we're only beginning to explore its potential.

Ultimately, most mental health disorders come about via the things we experience, via the sights, sounds and internal cogitations our brains end up dealing with. If therapists were able to cause the afflicted brains to perceive and experience things that counteracted the things that led to mental health issues, treating them would potentially be a lot easier than it is.

Psychedelics and VR have the potential to offer exactly that. And if we keep combining the two, who knows what we'll see? SF

by **DR DEAN BURNETT** (@Garwboy)
Dean is a doctor of neuroscience and an author. His latest book is Emotional Ignorance *(Guardian Faber, £14.99).*



Q&A

Email your questions to questions@sciencefocus.com or submit on X (formerly Twitter) at @sciencefocus

YOUR QUESTIONS ANSWERED

DONALD HODGES, VIA EMAIL

WHY DO MUSICIANS PULL SUCH WEIRD FACES WHEN THEY PLAY?

The facial expressions musicians show when playing may seem strange or exaggerated to an outsider, but all that gurning might actually serve a purpose.

Firstly, playing a musical instrument usually requires intense focus and concentration. Musicians often enter a state of 'flow', where they become completely absorbed in the music they're creating. These facial expressions can be a manifestation of the intense emotions and physical exertion that go hand-in-hand with musical performance. They're often subconscious – in fact, many of us will pull weird faces when we're deeply involved in an activity we care about.

Facial expressions can also help musicians communicate emotions and artistic expression. Musicians often use their facial expressions to convey the mood and interpretation of the music they're playing, which creates a more immersive and captivating musical experience. While making facial expressions may not directly make someone a better musician, they might contribute to the overall artistry and interpretation of the music.

Performing live music is also a rather nerve-racking experience, so it could also be that the performer is expressing those nerves through their face – furrowed brows and clenched teeth, for example.

Finally, making facial expressions can also have a physiological impact on the musician's performance. Some research suggests that certain facial movements can activate specific muscles and potentially improve muscle coordination, particularly in activities involving fine motor skills, such as playing an instrument. However, it's important to note that this relationship is still not well understood, and the extent to which facial expressions directly impact musical proficiency is a subject of ongoing investigation. ***NM***

DR HELEN PILCHER
Biology

PETE LAWRENCE
Astronomy

DR HELEN SCALES
Marine biology

DR EMMA DAVIES
Food and chemistry

CERI PERKINS
Environment

DR ALASTAIR GUNN
Astrophysics

DR CLAIRE ASHER
Nature

DR NISH MANEK
Health and medicine

LUIS VILLAZON
Dinosaurs

PROF PETER BENTLEY
Technology

"FACIAL EXPRESSIONS CAN ALSO HELP MUSICIANS COMMUNICATE EMOTIONS AND ARTISTIC EXPRESSION"

GETTY IMAGES, ALAMY ILLUSTRATION: HARRIET NOBEL

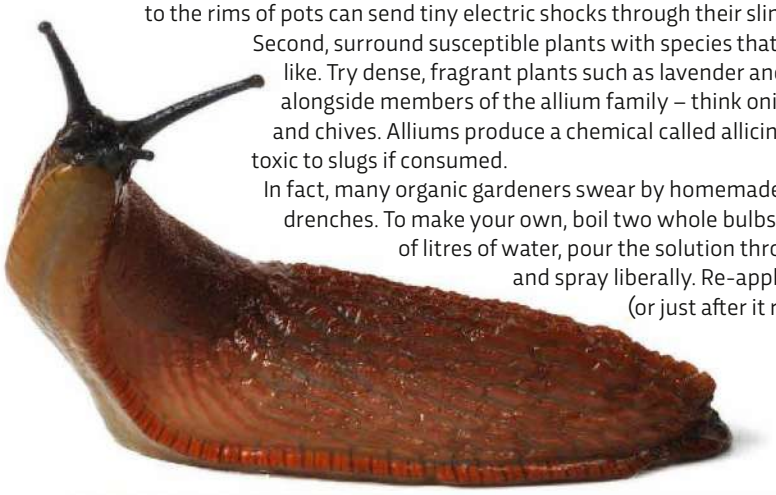
LORNA ANDERSON, BIRMINGHAM

ARE THERE ANY NATURAL SLUG REPELLENTS?

None that are as effective as the heavy-duty chemicals sold in garden centres, but a combination of the following strategies can help. First, install physical barriers that slugs are reluctant or unable to cross. Crushed eggshells can irritate a slug's soft underside; wood ash can dry up the slime they move on; and copper tape fixed to the rims of pots can send tiny electric shocks through their slime.

Second, surround susceptible plants with species that slugs don't like. Try dense, fragrant plants such as lavender and rosemary alongside members of the allium family – think onions, garlic and chives. Alliums produce a chemical called allicin, which is toxic to slugs if consumed.

In fact, many organic gardeners swear by homemade garlic drenches. To make your own, boil two whole bulbs in a couple of litres of water, pour the solution through a sieve, and spray liberally. Re-apply weekly (or just after it rains). ***CP***



LESLIE WILLIS, SALFORD

WHAT IS A RAINBOW TREE?

In the tropical rainforests of the Philippines, New Guinea and Indonesia, grows a tree that looks more like a painting than a plant. The rainbow eucalyptus (*Eucalyptus deglupta*) is named after the vibrant coloured stripes on its trunk, which appear because the trees shed their thin bark throughout life.

The brown outer bark peels off in long, narrow strips, revealing neon-green inner bark that gradually changes colour when exposed to air — transitioning to blues and purples, then shades of red, yellow and eventually brown. Surprisingly, this colourful tree's main commercial use is in the production of white paper. ***CA***

NATURE'S WEIRDEST CREATURES

PURPLE FROG

You could say that the purple frog resembles a turtle without its shell. That's what the good people of Idukki in Kerala say. Or you could say that this amazing amphibian looks like a bruised, bloated beanbag with beady eyes and a bootylicious backside. That's what I say.

Evolution rightly has no respect for conventional beauty standards. Instead, it sculpts and tweaks the forms of living things so they become adapted to their environment. The purple frog is a fossorial species, which means it's a burrower. Adults spend most of their lives underground, where their short, strong, spade-like hindlimbs are used for digging, and their hard-palmed forelimbs are used to drive their bodies downwards. Their small eyes reflect a life with little need for sight, while their tapered snout and small heads add to their triangular shape overall, which helps them forge their way through the damp earth of their forest homes. Their snouts are sensitive, with a protuberance that overhangs their small mouths. This helps them to probe around for termites (their favourite food), which are sucked up via their fluted tongues.

The mole-sized frogs live exclusively in the Western Ghats of southern India,

where individuals have been found in burrows, up to a metre (3ft) deep.

Adults emerge just once a year to breed. Males announce their exit from the underworld with an unusual vocal cry, that sounds like a chicken on helium. After that, mating is timed to occur with the pre-monsoon rains, enabling females to lay their eggs in shallow streams when the water levels are low.

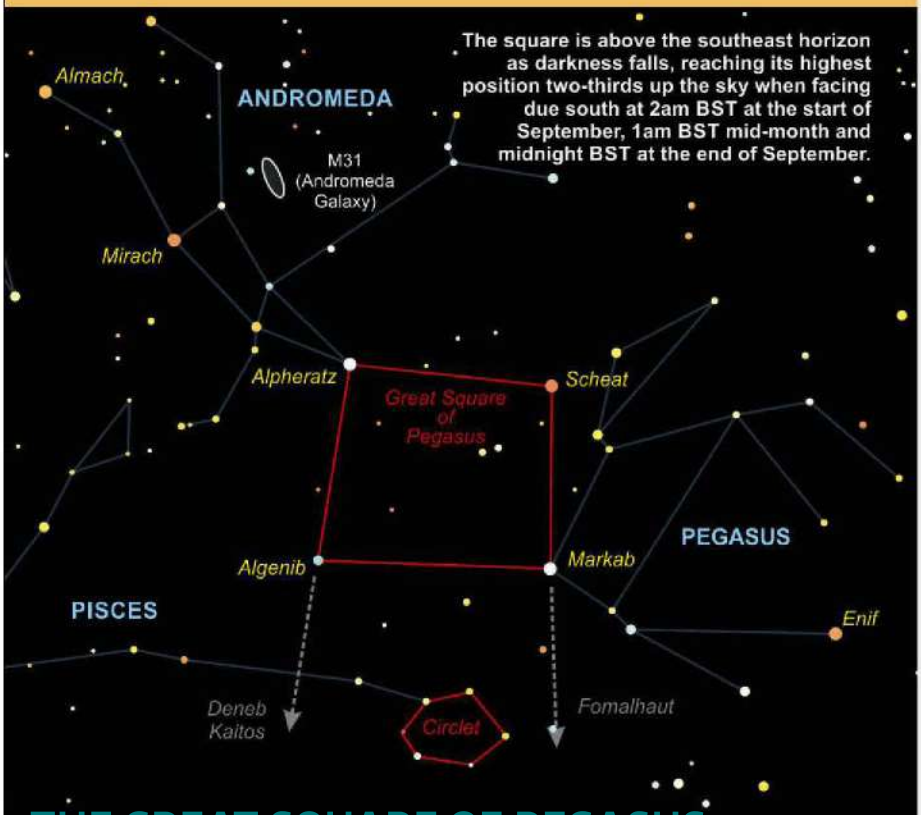
The tadpoles hatch as the rains pound down and trickling streams are transformed into fast-flowing torrents. Fortunately for the tadpoles, evolution has endowed them with strong, sucky mouthparts that help them to cling to the rocks. Unfortunately for the tadpoles, this makes them sitting ducks for local people who find them delicious and have been harvesting them for decades. The tadpoles can be swept from the rocks with a broom, and then collected in baskets downstream.

Along with habitat loss, climate change and fungal disease, this is one of the reasons for the purple frog's decline. The species is currently listed as 'near threatened' and conservationists are concerned that local extinctions caused by harvesting, could ultimately push the species to global extinction.

This would be a devastating blow. When it was first discovered and described scientifically, back in 2003, scientists called it a 'once in a century' find. DNA tests put the frog in a new family, with roots dating back over 130 million years. This means that the lineage has been around since before the breakup of the ancient supercontinent Gondwana. Ancestors of today's little frog witnessed the genesis of new continents, the demise of the dinosaurs, the evolution of mammals and the rise of our species. Let's hope it gets to keep digging for another few million years, at the very least. ***HP***

SANDESH KADUR/NATUREPL.COM X2 ILLUSTRATION: PETE LAWRENCE

ASTRONOMY FOR BEGINNERS



THE GREAT SQUARE OF PEGASUS

WHEN: LATE AUGUST – MID-SEPT-OCT 2023

The transition from summer to autumn skies is underway in the UK. The bright, dramatic stars of summer are gradually replaced by more subtle fare, led by Pegasus, the Flying Horse. This unusual mythological creature is complicated by the fact that it's only the upper part of the horse's body that's represented. Oh, and it appears upside-down in the sky, Pegasus's head sits in the constellation's southwest corner, with the star Enif marking its nose.

The horse's torso is represented by a large geometric shape known as the Great Square of Pegasus. On charts it looks quite prominent, but in reality, its stars aren't that bright. The sides of the square aren't of equal length either and to cap it all, only three of the stars actually belong to Pegasus! The northeast corner star is Alpheratz, the alpha star of Andromeda, the Chained Princess. It once belonged to Pegasus, as Sirrah or Delta Pegasi, but was formally reassigned to neighbouring Andromeda in 1930.

The square is useful as a guide. Immediately south of its southern edge lies the faint Circlet asterism within Pisces, the Fish. Use the western side, following its line south for three times its length to arrive at bright Fomalhaut in Piscis Austrinus, the Southern Fish. Follow the eastern side south a little over twice the side's length and you'll arrive at bright Deneb Kaitos 'the whale's tail', a star belonging to Cetus, the Whale.

Extend the diagonal from Markab through Alpheratz in the northeast to locate three stars of similar brightness in Andromeda. Locate the middle star Mirach, then make a right angle turn to head up the sky. Keep going for half the length of the square's southern edge to arrive at the Andromeda Galaxy, M31. *PL*

by PETE LAWRENCE
(@Avertedvision)
Pete is an astronomy expert and presenter on The Sky at Night.

WATCH *THE SKY AT NIGHT* ON BBC FOUR AND BBC IPLAYER
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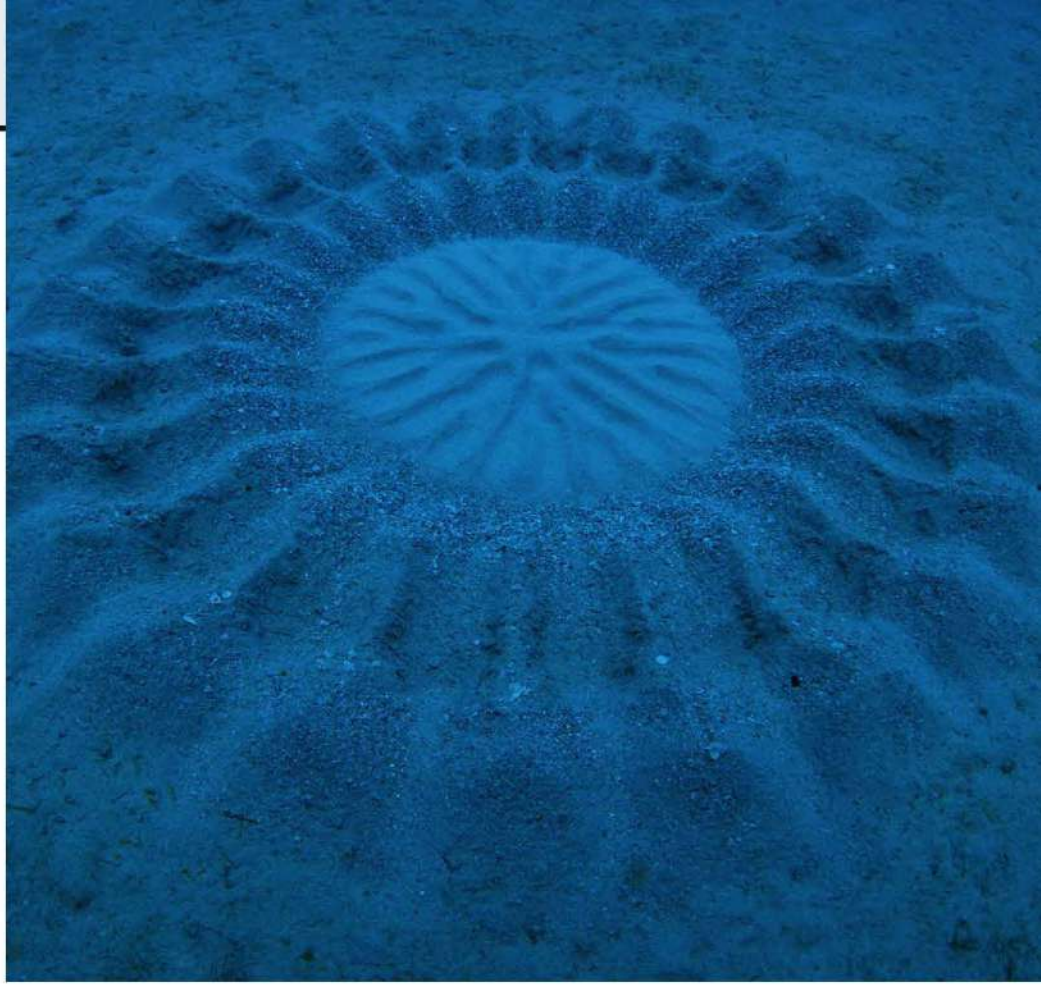


JERMAINE REYES, VIA EMAIL

HOW ARE UNDERWATER CROP CIRCLES MADE?

Several years ago, in the subtropical waters of southern Japan, divers spotted large geometric shapes sculpted in the sandy seabed. The circles were roughly two metres (6ft) across and formed of two concentric rings with spokes radiating from the centre. They were an aquatic version of unexplained crop circles. No one could work out what, or who, had made these mysterious shapes.

Then, a team of scientists finally caught sight of the seabed artists in action. They saw a small, male pufferfish (from the *Torquigener* genus), around 12cm (4in) long, darting across the sand, shimmying his fins and creating patterns in the sand. After that, more sand-sculpting puffers were spotted drawing circles on the seabed, each one performing a similar series of steps.

First, a male traces basic circular shapes, then embellishes them with ridges by swimming inwards at different angles. Next, he fills in the circle with doodles of random squiggly lines. For a finishing touch, the male gathers up pieces of dead coral and seashells to decorate his seabed creation. The whole process takes at least a week.

The purpose of these shapes becomes clear when female pufferfish show up and inspect a male's artworks. As it turns out, these shapes are nests. The circular design seems to channel fresh water towards the middle of the nest, so no matter which way the current is flowing, fresh oxygen-rich water is swept into the central spawning area, creating ideal conditions for egg development.

If a female pufferfish likes the look of a nest, she'll lay her eggs in the middle then swim off, leaving the hard-working male to hang around for another six days, guarding the nest and the growing eggs, while his artwork gradually crumbles and gets swept away. Every time he wants to attract another mate, he has to build a new nest. ***HS***

MARIYAH SILVA, LISBON

HOW MANY PEOPLE WOULD A *TYRANNOSAURUS REX* HAVE TO EAT TO SUSTAIN ITSELF?

An adult *Tyrannosaurus rex* weighed about seven tonnes. A crocodile eats about five per cent of its body weight per week, whereas a warm-blooded predator, like a lion, needs to eat 25 per cent of its body weight each week. *T. rex* probably had a metabolism somewhere in between. So if we say 15 per cent, this would translate to more than a tonne of meat per week, or about two people a day. In reality, apex predators normally have much less regular meals, so *T. rex* might starve for a month and then eat a busload of time travelling tourists all at once. ***LV***

NATURE PRODUCTION/NATUREPL.COM, GETTY IMAGES ILLUSTRATION: HARRIET NOBEL

JONNY MALONE, OHIO

WHY DO PUMPKINS GROW SO BIG?

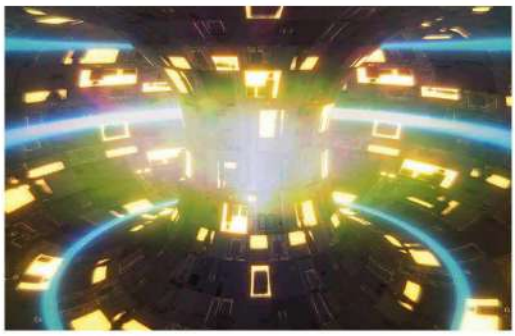
Prize-winning pumpkins just keep getting bigger, thanks to careful seed selection, plenty of growing space and gallons of water. The current record belongs to a gargantuan 1,226kg (2,702lb) pumpkin grown by Italy's Stefano Cutrupi. Some varieties of pumpkin, such as the Atlantic Giant, are genetically predisposed to grow to spectacular sizes.

Pumpkins grow rapidly during a cell division phase that lasts far longer than in their gourd relatives such as cucumbers. After division, the cells expand for up to two months, giving larger cells than in other fruits.

Pumpkins are also gifted higher levels of specialised tissue called phloem, which transports sugars to where it's needed for growth. The one thing that prize growers haven't been able to overcome so far is a flat base when the pumpkin becomes too heavy to hold its shape. ***ED***

JACQUELINE BURTON, WORCESTER

HOW SURE ARE WE THAT FUSION REACTORS WILL ACTUALLY WORK?



Scientists and engineers are very confident that nuclear fusion energy will one day be a reality. The technology offers clean, affordable and almost limitless supplies of energy. There are, however, some serious technological problems to be solved.

The technology will use the same process that converts hydrogen into heavier elements in the cores of stars, thereby releasing large amounts of energy. These reactions occur in 'plasma' – where atoms have been stripped of their electrons – at enormous pressures and at temperatures exceeding 10 million°C (18 million°F) . Without the high pressures found in stellar cores, replicating these nuclear reactions on Earth requires even higher temperatures; about 100 million°C (180 million°F).

Heating nuclear fuel to these kinds of temperatures, safely confining it, maintaining its stability and extracting the resultant energy, are the main challenges for fusion energy. There are many competing engineering solutions to these problems.

One such solution confines the hot plasma using strong magnetic fields so that the plasma is held firmly in a 'toroidal' shape (or doughnut). The magnetic fields also squeeze the plasma to increase the pressure. Then, a powerful electric current is induced in the plasma. Microwaves and/or accelerated particles are also fired into the fuel increasing its temperature until nuclear fusion reactions begin. The released energy, in the form of fast-moving neutrons, is captured in a 'blanket' surrounding the plasma.

Currently, engineers have succeeded in producing fusion energy for short periods of time with a small amount of energy captured. Although the research is encouraging, we may not be able to fully solve the engineering challenges for another 30 years or so.

It's more or less certain that one day nuclear fusion will supply humanity's energy needs from fuel that's cheaply extracted from plentiful seawater. The technology will produce no harmful by-products, radioactive waste or greenhouse gases, and will be very safe to operate. ***AG***

Millions of years in the making

Fossilisation captures moments from the distant past and offers a glimpse of an Earth that time almost forgot...

The dinosaurs lived during the Mesozoic Era, a time in Earth's history that lasted for approximately 186 million years.

The dinosaurs' reign was ended by an asteroid that hit what is now Chicxulub in Mexico. It killed around 75 per cent of life on Earth.

The dinosaurs' existence is preserved through fossilisation, which occurs when sediment slows down decomposition.

Digging for dinos

Infographic by James Round

Dinosaurs hold a special place in our imaginations. These ancient animals seem almost too strange to be real, and yet they walked the Earth for around 186 million years – far longer than we've existed. Although they died out about 65 million years before the first humans appeared, we've learnt a lot about them through the incredible process of fossilisation. The secrets of the dinosaurs are lying there, beneath our feet, just waiting to be uncovered.

The age of reptiles

The Mesozoic Era, when dinosaurs existed, is split into three geological Periods...

Triassic Period — **252 to 201 mya***

Dinosaurs first evolved on an Earth very different from the one we live on today. The global climate was hot and dry – perfect for reptiles – and the planet consisted of a single landmass called Pangaea.

Jurassic Period — **201 to 145 mya**

The end of the Triassic Period saw a mass extinction, but the dinosaurs survived and thrived. Pangaea split in two, while temperatures fell, rainfall increased, and Earth's surface was gradually covered with lush vegetation.

Cretaceous Period — **145 to 66 mya**

As Pangaea broke further apart, dinosaur species began to evolve independently around the world. During this period, the climate was warm and humid, and sea levels repeatedly rose and fell.

***million years ago**

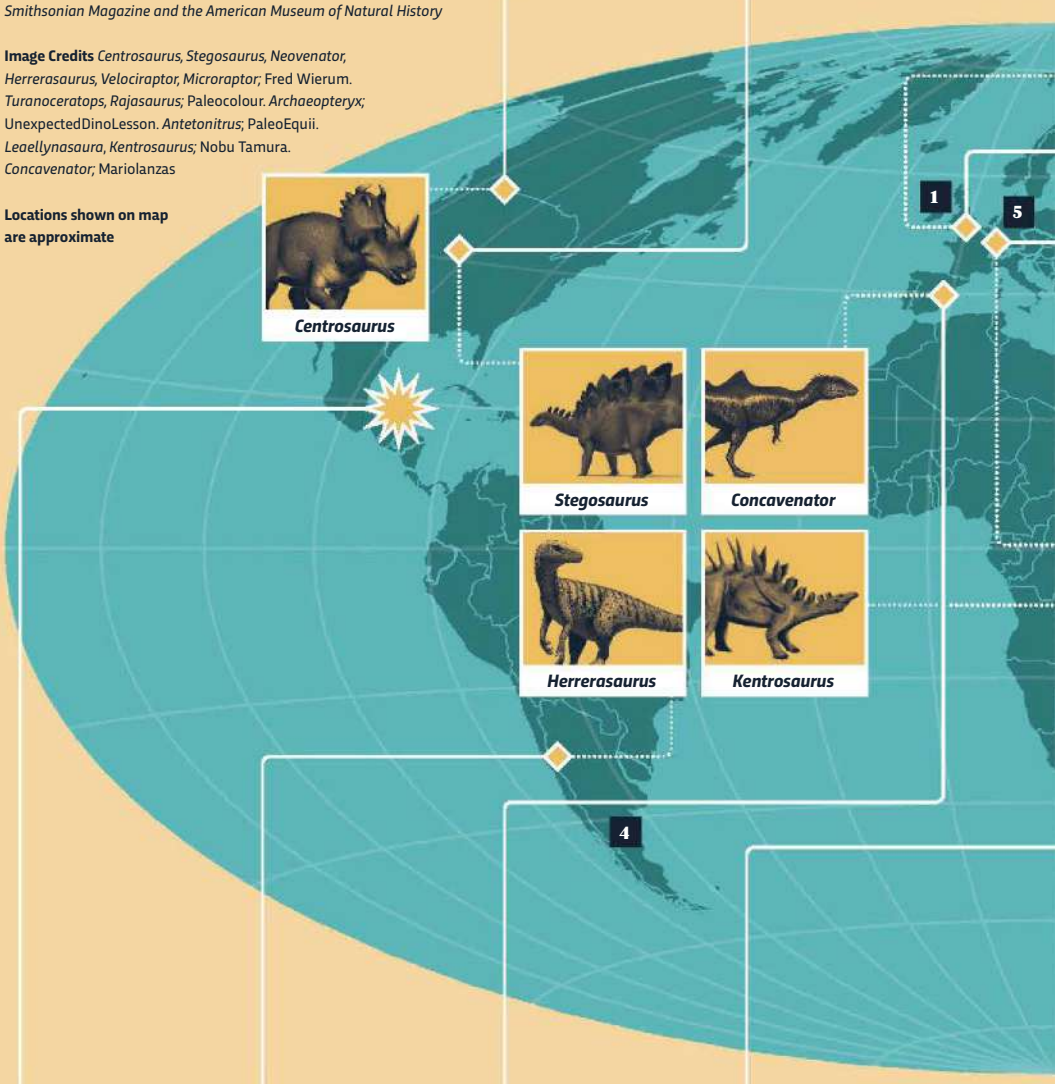
Some key dinosaur fossil sites around the world

Dinosaur remains have been discovered in geological formations on every continent on Earth, most of them in North America and Europe. Plotted here are some of the most famous sites, along with an example of a genus that was discovered there.

Sources *The Paleobiology Database, BBC, Natural History Museum, ThoughtCo., Scientific American, Wikipedia, The Conversation, EarthSky, Smithsonian Magazine and the American Museum of Natural History*

Image Credits *Centrosaurus, Stegosaurus, Neovenator, Herrerasaurus, Velociraptor, Microraptor;* Fred Wierum. *Turanoceratops, Rajasaurus;* Paleocolour. *Archaeopteryx;* UnexpectedDinoLesson. *Antetonitrus;* PaleoEquii. *Leaellynasaura, Kentrosaurus;* Nobu Tamura. *Concavenator;* Mariolanzas

Locations shown on map are approximate



Canada

Dinosaur Park in Alberta is one of Canada's finest fossil sites, and includes the world's greatest variety of species, with a wealth of discoveries from the Late Cretaceous Period.

United States

The US is home to some of the best fossil sites in the world, none more famous than the Morrison Formation, which dates to the Jurassic Period and stretches across 13 states.

Mexico

The Yucatán Peninsula is the site of the Chicxulub crater where, 66 million years ago, a roughly 10km-wide (6-mile) asteroid hit Earth and drove the dinosaurs to extinction.

Argentina

During the late Triassic Period, Valle de la Luna was a volcanically active floodplain. Today it's the site of some of the oldest dinosaur remains that have ever been found.

Spain

The Las Hoyas Formation features a unique Cretaceous wetland ecosystem with fossils of an exceptional quality, perhaps because of microbial mats aiding the preservation process.

South Africa

The Elliot Formation features specimens from the Late Triassic and Early Jurassic periods, and has yielded rare discoveries, such as dinosaur eggs with the intact embryo remains.

Fossils are mostly found in sedimentary rocks, where sand and mud settle around dinosaur remains and are compacted into rock.

Dinosaur fossils are rare. Because of how fossils are formed, 99 per cent of discoveries are from marine animals.

Since the first dinosaur fossil was reported, we've discovered roughly 11,000 dinosaur fossils around the world.

And from these fossils, palaeontologists have identified around 1,000 dinosaur species.

United Kingdom

The Isle of Wight has produced such an impressive number of specimens from the Cretaceous Period that it's earned the nickname Dinosaur Island.

Germany

The Solnhofen Limestone Beds hold the preserved remains of an entire Jurassic ecosystem. Many species are captured in amazing detail in the 150-million-year-old sediment.

Mongolia

The Gobi Desert hosts a number of notable fossil sites. However, none is more striking than the remote Flaming Cliffs, where the iconic *Velociraptor* was first discovered.

China

The Liaoning Province has one of our planet's most important fossil beds, boasting some of the best preserved specimens known to science; many still with skin texture and feathers.

Tanzania

First discovered in 1906, the Tendaguru Formation is responsible for a number of important palaeontological discoveries, and is considered the richest Late Jurassic site in Africa.

India

Thanks to its numerous sites of interest, such as the Lameta Formation from the Cretaceous Period, palaeontologists regard India as a place deserving of more focus and exploration.

Uzbekistan

The Bissekty Formation in the Kyzylkum Desert features a diverse selection of fossilised specimens from the Late Cretaceous Period, including theropods and sauropods.

Australia

Dinosaur Cove in southern Australia has revealed a unique assemblage of dinosaur species that were well-adapted to conditions of extreme cold and darkness.

Notable discoveries

While every dinosaur discovery is a scientific marvel, some finds go further and reveal something new or unexpected, challenging the past that we thought we knew and bringing us a little bit closer to the ancient world.

1 Introducing Dinosauria

The first dinosaurs were formally identified from fossils in 1842 by Sir Richard Owen, who coined the term Dinosauria. It's often translated from its Greek roots to mean 'terrible lizard', even though Owen referred to them as 'fearfully great'.

2 The oldest dinosaur

The fossil of *Nyasasaurus*, discovered in Tanzania, is particularly special as it's currently the earliest known dinosaur, having lived over 240 million years ago.

3 A bunch of baby dinosaurs

An extraordinary nest housing 15 young *Protoceratops* was found in Mongolia, giving palaeontologists new insights into dinosaur postnatal development and parental care.

4 The largest dinosaur

The largest dinosaurs were Titanosaurs, the biggest example of which was found in Argentina. This giant weighed over 60 tonnes and may have been 37m (120ft) long.

5 Finding feathers

Few dino discoveries have proved as exciting as *Archaeopteryx lithographica*. The fossil has both feathers and teeth, and provided a missing link between birds and reptiles.

6 Eggs is dinosaur eggs?

An expedition to the Gobi Desert in 1923 uncovered the first fossilised dinosaur eggs, proving that these ancient species reproduced like many modern-day reptiles.

QUESTION OF THE MONTH

LOUISE WILSON, CUMBRIA

WHY DO I GET A LUMP IN MY THROAT WHEN I'M ABOUT TO CRY?

This is a common sensation known as 'globus sensation', or 'globus pharyngeus' in medical terms.

The feeling of having a lump in your throat is typically caused by a tightening of the muscles in your throat and neck region. These muscles include the muscles of the pharynx (the tube that connects your mouth to your esophagus) and the muscles surrounding your larynx (voice box).

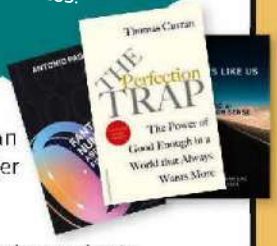
When you experience strong emotions, such as sadness or grief, your body undergoes various physiological changes, and the muscles in your throat can become tense or constricted.

One of the primary reasons for the lump in the throat sensation, is the activation of the body's stress response system – also known as the fight-or-flight response. When we're in an emotionally charged state, the sympathetic nervous system is triggered, leading to the release of stress hormones like adrenaline. These hormones can cause a variety of physical responses, including the tightening of muscles throughout the body, including the throat.

When the stress response system switches on, it needs to deliver oxygen all over your body to make it easier for you to fight or flee. To spread oxygen to all of your muscles, your body must first breathe it in. In an effort to take in more oxygen, the nervous system sends signals to the glottis – the opening in your throat that helps bring air into lungs – to stay open for as long as possible. In other words, your throat opens wider than normal, because a larger opening means more oxygen can enter.

WINNER

The winner of next issue's Question of the Month wins a **trio of hardback popular-science books**: *Fantastic Numbers and Where to Find Them*; *The Perfection Trap*; and *Machines Like Us*, worth over £65.



You don't actually feel your glottis opening wide, but you might sense the muscle tension caused by your body trying to keep your glottis open even when you swallow. This creates a feeling of constriction or a lump-like sensation in your throat.

As well as this, the lump in the throat can also be influenced by psychological factors. Emotions can have a profound impact on our physical sensations, and the anticipation of crying or expressing strong emotions can trigger a tightening of the throat muscles.

While it might feel annoying and even painful, the sensation won't harm you. If the lump feels uncomfortable, there are a few strategies that may help. Firstly, taking slow, deep breaths can help relax the muscles and reduce tension in your throat area. Engaging in relaxation techniques such as deep breathing exercises, meditation or mindfulness practices can also be beneficial.

In some cases, seeking emotional support by talking to a trusted friend, family member, or therapist can help address the underlying emotions that may be contributing to the sensation. Additionally, stress-management techniques, such as taking regular exercise, getting adequate sleep and engaging in activities that promote relaxation, can be helpful in reducing overall tension and anxiety. ***NM***

VICTORIA SHIELDS, VIA EMAIL

HOW CAN YOU SPOT A DEEPFAKE?

Generative artificial intelligences (AIs) are often large multi-model 'deep' neural networks that have been trained on lots of images, videos and associated text. Give a trained model a description of a picture you want, and it can invent new images to match. A generative AI such as DALL-E 2 or Midjourney can create remarkable new images of almost anything, in any style you like, from photorealistic to cartoon.

Combine the power of generative AIs with other AIs that can automatically detect people in images and video, and you have the power of a special-effects artist: you can switch the face or body of someone, almost invisibly. Use other generative AI to reproduce the voice and you can entirely fake photos and videos, making it look and sound as though someone else was there when they weren't – or even removing them entirely and

filling in the background, as in the BBC drama *The Capture*. This is a deepfake.

Generative AI systems are amazing, but the first iterations of this technology were plagued by subtle, yet telling errors. Look at the details, especially if an irregular object such as a hand or branch passes across a face, and you may see inconsistencies where the original face peeks through. Look for colours, shadows or backgrounds that don't match. And look for things that might be impossible or bizarre, like weird hands, a foot merged with a tree, or even too many arms.

Many of these tell-tale signs are disappearing as the technology improves. This is the unfortunate side-effect of making better photo and video editing software – the better the software becomes, the easier it is for anyone to make undetectable misinformation and deepfakes. Adobe, who makes this kind of software, is also trying to introduce content authentication so that, in future, we can tell what is real and what isn't. Let's hope they succeed. ***PB***

CHRISTIAN BARKER, VIA EMAIL

IS IT TRUE THAT AFRICA IS SPLITTING IN TWO?

It's easy to forget that the earth beneath our feet is constantly moving – that the continents we stand on are little more than thin tectonic plates floating and jostling atop a churning sphere of hot rock. Over geological timescales of millions of years, these tectonic plates grind past one another, wrench apart, and undergo extreme slow-motion collisions that warp and buckle their edges, erect mountain ranges and widen oceans.

These processes are usually imperceptibly slow, with movement on the order of just a few centimetres per year – or about as fast as your toenails grow. But occasionally something happens to remind us of the planet's restless interior.

The world witnessed dramatic evidence of this back in March 2018, when an enormous crack opened in the ground in southwestern Kenya. The tear, which appeared suddenly after heavy rains, measured several kilometres in length and swallowed a section of the Nairobi-Narok highway.

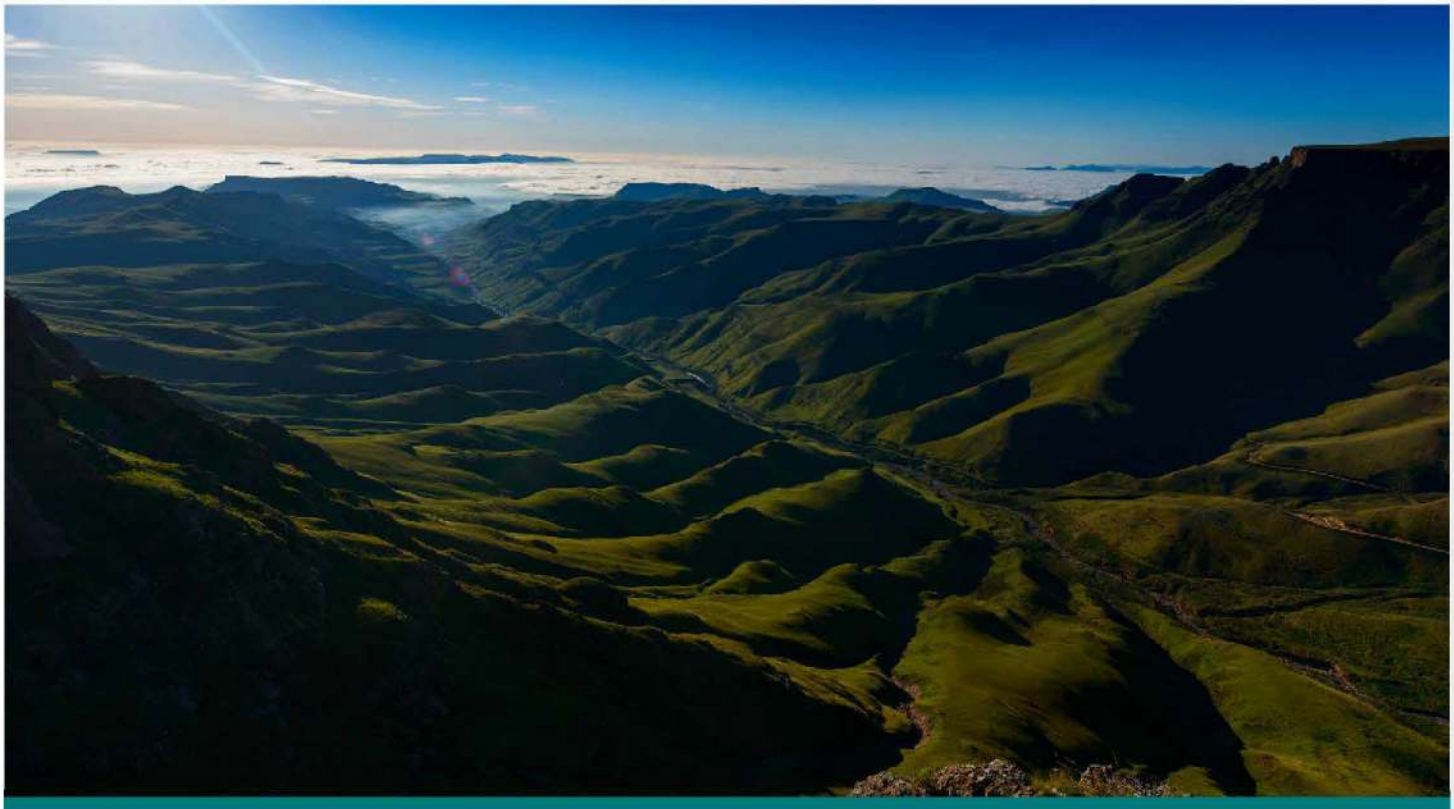
The location of the crack, within the Kenyan Rift Valley, reignited a decades-old debate about whether Africa will one day break apart. The Valley is part of a region called the East African Rift, one of the most tectonically active regions in the world. The rift, which began developing about 25 million years ago, extends over a staggering 3,500km (2,174 miles), from the Red Sea in the north all the way to Mozambique in the southeast of the African continent. Seismic and volcanic activity occurs along its entire length, and is responsible for creating mountains including Kilimanjaro and Mount Kenya.

In the past, scientists thought that Africa sat upon a single tectonic plate. But since the 1970s, evidence has been mounting that the African plate is rupturing into two new plates – dubbed the Nubian and Somali plates – along the East African Rift.

Geologists and geophysicists are still debating what might be causing this to happen. The current leading theory is that plumes of heat within Earth's mantle are making the lithosphere (the crust and solid upper mantle) beneath Kenya and Ethiopia dome and stretch. The thinning lithosphere has generated huge volcanic eruptions called flood basalts – which send lava gushing from emerging fissures like flood waters – and fractured the brittle continental crust into a series of faults. From above, these faults, which together make up the greater Rift Valley, look like deep crevices and elongated basins separated by regions of higher land.

GPS measurements show that across the East African Rift, the Nubian and Somali plates are diverging at an average rate of 7mm (0.2in) per year, slowly pulling the continent apart. Today, the rift remains above sea level, but as it widens, the land within the valley will sink. Eventually, oceanic waters could flood in, separating the entire Horn of Africa from the mainland. The jury's still out on whether this will happen, but if it did it would take tens of millions of years. The Red Sea and the Gulf of Aden are examples of similar rifts at more advanced stages of evolution.

As for the crack that alarmed the world in 2018 – the consensus among geologists today is that it was a pre-existing crevice that had lain undetected because it was packed with volcanic ash from eruptions in the distant past. It was suddenly exposed during heavy rains when the deep layers of waterlogged ash collapsed. Panic over – for now, at least. ***CP***



GETTY IMAGES, ALAMY ILLUSTRATION: HARRIET NOBEL

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

THE EXPLAINER

THE BRAIN

EXPLORE THE WONDERS OF YOUR GREY MATTER, THE ORGAN THAT MAKES YOU *YOU*

"I am a brain, Watson," Sherlock Holmes told his assistant. "The rest of me is mere appendix." While most of us don't operate on quite the same level as Sir Arthur Conan Doyle's fictional super-sleuth, it's true that everything we know about the world – and ourselves – is contained within our brains, to which our bodies are, if not necessarily appendices, then certainly largely subject to. Our brains control our thoughts and actions, and are unique to each of us. Boasting 86 billion neurons and a 100 trillion connections, they're so complex that it's almost impossible for us get our heads around them, so to speak. But let's try...

What's inside your brain?

1. CEREBRUM
Encompassing most of the wrinkly structure we recognise as the brain, the cerebrum is divided into two hemispheres (left and right) and four regions, or lobes.

2. FRONTAL LOBE
A large section behind your forehead with a wide variety of responsibilities, ranging from movement and behaviour to language and emotions.

2.1. PRIMARY MOTOR CORTEX
This is a bunch of nerves found in the dorsal section of the frontal lobe that control voluntary movements.

2.2. SUPPLEMENTARY MOTOR CORTEX
Also part of the frontal lobe, the supplementary motor cortex is involved in the planning of your movements.

3. OCCIPITAL LOBE
Heavily involved in vision – damage to this lobe can cause problems with reading, writing and colour perception.

4. PARIETAL LOBE
Crucial to interpreting the outside world, the parietal lobe processes sensory and spatial information.

4.1. SOMATOSENSORY CORTEX
Part of the parietal lobe, this is a central destination for sensory info collected all over the body.

5. TEMPORAL LOBE
Involved in hearing and memory, the temporal lobe helps us remember music, for example, and understand language.

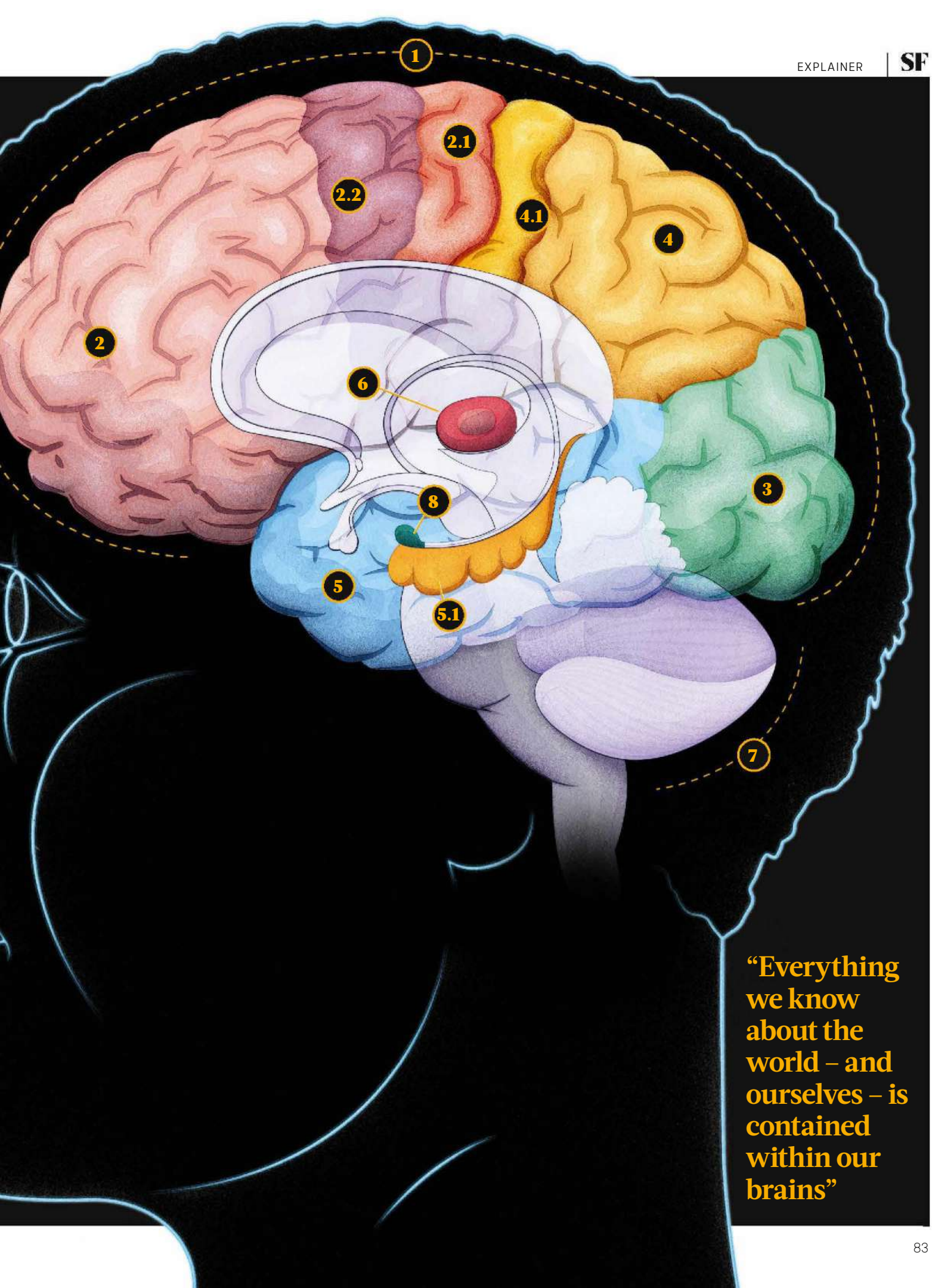
5.1. HIPPOCAMPUS
A curved part of the limbic system (the 'primitive' brain) associated with memory and decision-making.

6. THALAMUS
Filters sensory and movement information that is passing between the body and brain.

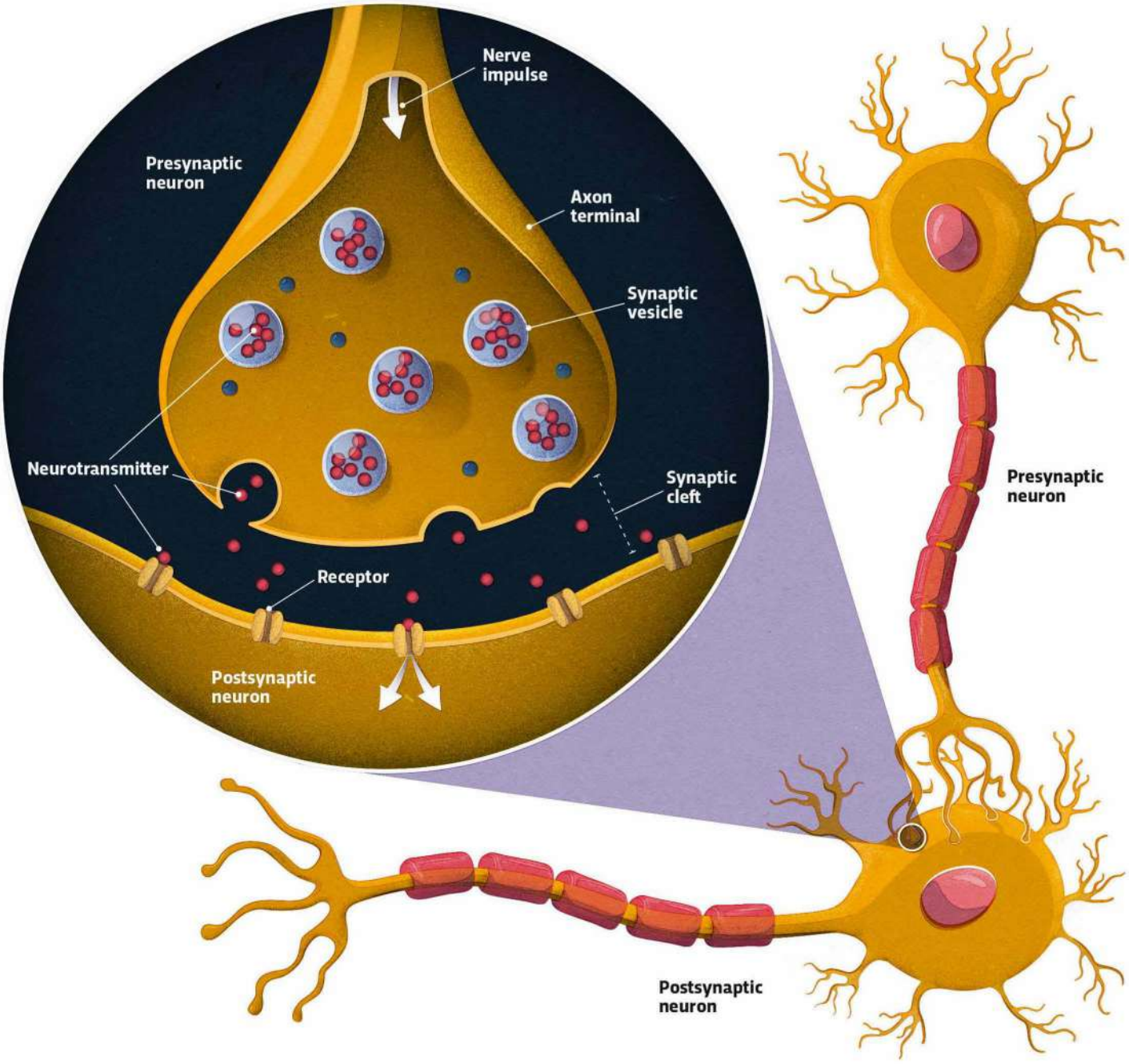
7. CEREBELLUM
Densely packed with neurons, the cerebellum is important in movement and balance.

8. AMYGDALA
An almond-shaped component of the limbic system with roles in stress, emotions and memory.

ILLUSTRATION: DANIEL BRIGHT



"Everything we know about the world – and ourselves – is contained within our brains"



How does the brain work?

Big question. The brain is often thought of as a biological computer: a very efficient one that can handle a tremendous amount of work at much lower powers than your average laptop. But neuroscientists don't like this analogy, and it's unhelpful for understanding how the brain works, since most of us don't understand how computers work either. Instead, we might consider what neurons – key components of our brains – do to allow us to think, move and sense. Neurons, like other nerve cells, are tree-structured carriers of signals that speed along the neurons' trunks, from branches to roots, where they're passed to other neurons by the release of chemicals (neurotransmitters) across the gaps (synapses).

A thought is the result of the signals spreading through networks of neurons. Movements rely on messages being sent from the brain to neural outposts in our muscles, while sensory inputs depend on them travelling the other way. We know that these pathways have to function for our brains to work, but scientists are still far from understanding the circuitry for memory, pain, emotions, attention and decision-making. Though some of these functions are traditionally tied to specific areas of the brain, recent evidence suggests it's not that straightforward – the brain's duties can't be so neatly divided.

Do we really use just 10 per cent of our brains?

No. That's a myth. While it may be true that if you took a snapshot of activity in the human brain, then less than 10 per cent would appear to be firing at any one moment, it's certainly not the case that 90 per cent of the brain is useless.

That would make no sense, since evolution is pretty good at getting rid of bits of the body that don't make any useful contribution. Hence we no longer have tails, fur or claws.

Experts are more of the mind that we do need all of our brains, just not all of the time. In 2020, UK researchers found that mentally draining tasks divert energy away from other processes and, as the brain has a limited energy supply, this probably puts a cap on the number of tasks it's capable of carrying out simultaneously.

"Experts are more of the mind that we do need all of our brains, just not all of the time"

How do our brains compare to those of our ancestors?

Remains of *Australopithecus afarensis* – ape-like animals related to the famous 'Lucy' skeleton discovered in 1974 in Ethiopia – suggest that our three-million-year-old ancestors' brains were about a third of the size of ours. But Lucy's relatives were smaller than modern humans. Even the heavier males of her species only weighed in at around 42kg (93lbs), the average weight of a 12-year-old human. So perhaps a more useful comparison is brain size as a proportion of bodyweight. While Lucy and her relatives' brains made up around 1.3 per cent of their total bodyweight, those of the first *Homo* species that lived about two million years ago made up closer to 1.7 per cent. Our own, more advanced brains account for 2.2 per cent of our bodyweight. However, recent research shows that although *A. afarensis* brains were organised like those of apes, they took longer to grow, meaning the primates had a longer childhood – just like modern humans.

ABOVE The skull of our ancester 'Lucy' (left) was only a little smaller than a modern human's
OPPOSITE A diagram showing how signals are transmitted between neurons

GETTY IMAGES, ALAMY ILLUSTRATION: DANIEL BRIGHT

21ST-CENTURY BRAIN SCIENCE: A BRIEF HISTORY OF SURPRISING STUDIES

2000

Brain scans of London taxi drivers suggest the hippocampus (a region involved with spatial memory) expands to accommodate navigational demands. The study shows taxi drivers' hippocampi are bigger than those of non-taxi drivers and that their size increases with time spent in the job.

2005

A US study links big brains to being smart, claiming to put an end to a centuries-old debate. However, neuroscientists still dispute the connection, arguing that intelligence is more about how our brains are organised than their size.

2010

Brain recordings made by US researchers suggest brain 'coupling' occurs between two people when one is listening to the other speak. The harder one person listens, the more closely their brain activity resembles that of the speaker.

2015

Neuroscientists claim they have created false memories in mice by stimulating the reward centres in their brains when they visit a particular location. The implanted memories apparently fool the mice into returning to the same spot again and again.

2020

Researchers unveil a 'plug-and-play' device that can be implanted in a paraplegic person's brain, allowing them to control a cursor on a computer screen using just their thoughts. The device uses AI to match the person's brain activity to their cursor movements.

"Maintaining a healthy lifestyle can slow memory decline"

What can we do to keep our brains in tip-top condition?

Some decline in brain functioning is inevitable as we get older. But with age also comes an increased risk of certain neurological conditions, such as dementia and stroke.

Dementia affects around a third of people over the age of 90. While science hasn't (and probably won't) find a way to stop to this deterioration, there may be things we can do to slow it down, or at least avoid speeding it up.

Unfortunately, current research suggests it requires more effort than simply eating oily fish twice a week. Earlier this year, a 10-year-long study of more than 29,000 adults over the age of 60 showed that maintaining a healthy lifestyle can slow memory decline – even in people with genetic factors that make them more susceptible to dementia.

But for those who took part, a 'healthy' lifestyle meant keeping on top of a whole range of factors, from diet and exercise to social activities and brain-stimulating activities such as reading and writing.

by **HAYLEY BENNETT** *(@gingerbreadlady)*
Hayley Bennett is a science writer based in the UK.

ALAMY ILLUSTRATION: DANIEL BRIGHT

The Royal Institution
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CHRISTMAS LECTURES
From the Royal Institution

Ticket ballot now open!
14 September – 11 October

This year's CHRISTMAS LECTURES with prof Mike Wooldridge will explore *the* topic of the moment, Artificial Intelligence. And you could be there to watch the live filming.

The ticket ballot is now open! Entry is exclusively for Ri Members and Patrons, so if you've been thinking of getting more science for less, it's the perfect time to join our community.

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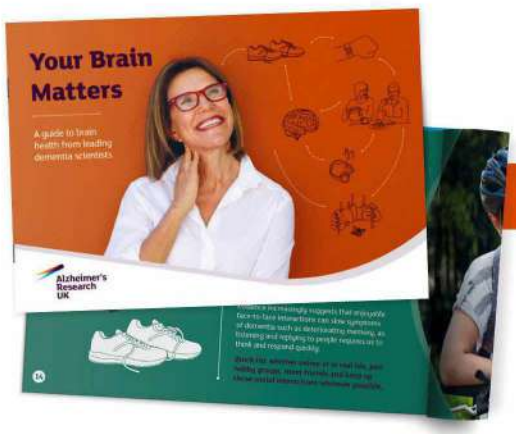
"DID YOU KNOW UP TO 40% OF DEMENTIA CASES COULD BE PREVENTED?"

Prof Anne-Marie Minihane, University of East Anglia

FREE guide from experts



Dementia is caused by diseases and, while age and genes play a role in your risk, there are things you can do to protect your brain health. Get your **FREE** Your Brain Matters guide from Alzheimer's Research UK and leading scientists like Professor Anne-Marie Minihane for information and tips on reducing your risk of dementia.

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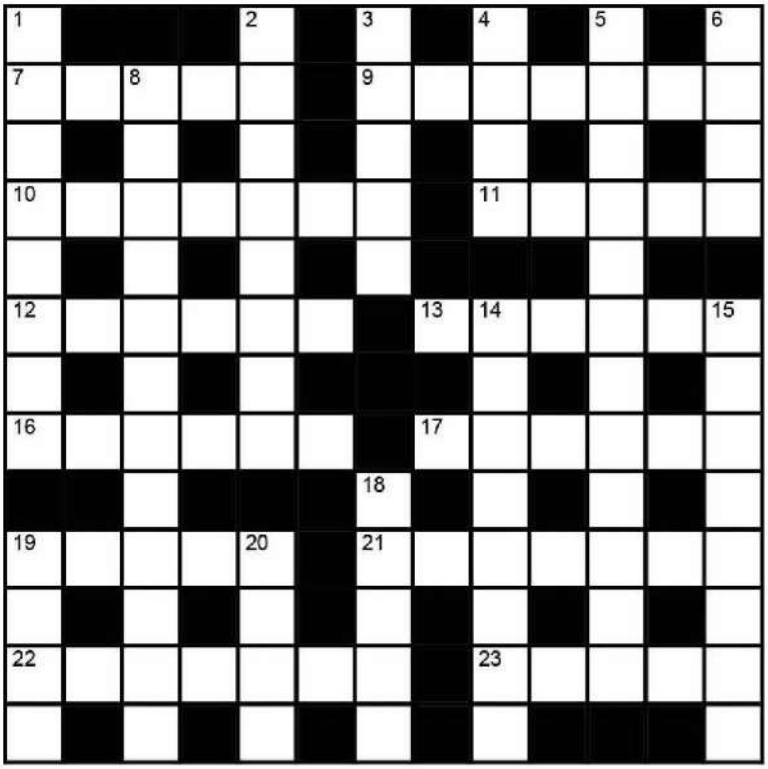

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ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

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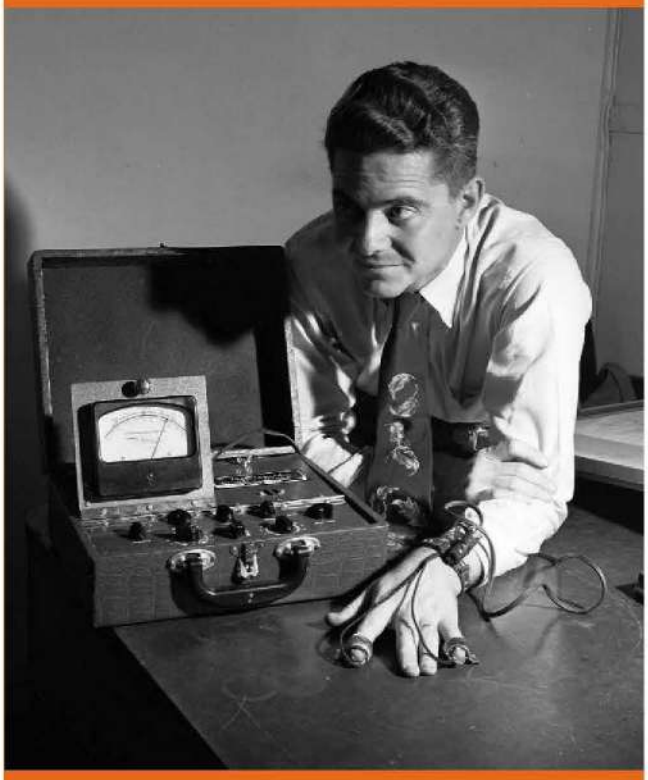
HOW TO SPOT A LIAR

The new psychological tools to tell if someone's fibbing (spoiler: it's not flaming underwear)



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PLUS

MISSION TO A METAL WORLD

Could the nickel-iron Psyche asteroid once have been a planetary core? NASA's new orbiter intends to find out

MONSTER SCIENCE

The real-life explanations for the horrors of Halloween

ON SALE 12 OCTOBER

SF

POPCORN SCIENCE

Could an AI really beat humans in a real-life war?

There's no need to worry about a robot uprising. We can always just pull the plug, right...? RIGHT?

by **STEPHEN KELLY**

New science-fiction movie *The Creator* imagines a future in which humanity is at war with artificial intelligence (AI). Hardly a novel concept for sci-fi, but the key difference here – as opposed to, say, *The Terminator* – is that it arrives at a time when the prospect is starting to feel more like science fact than fiction.

The last few months, for instance, have seen numerous warnings about the 'existential threat' posed by AI. For not only could it one day write this column better than I can (unlikely, I'm sure you'll agree), but it could also lead to frightening developments in warfare – developments that could spiral out of control.

The most obvious concern is a future in which AI is used to autonomously operate weaponry in place of humans. Paul Scharre, author of *Four Battlegrounds: Power in the Age of Artificial Intelligence*, and vice president of the Center for a New American Security, cites the recent example of DARPA's (the Defense Advanced Research Projects Agency) AlphaDogfight challenge – an aerial simulator that pitted a human pilot against an AI.

"Not only did the AI crush the pilot 15 to zero," says Scharre, "but it made moves that humans can't make; specifically, very high-precision, split-second gunshots."

Yet the prospect of giving AI the power to make life or death decisions raises uncomfortable questions. For instance, what would happen if an AI made a mistake and accidentally killed a civilian? "That would be a war crime," says Scharre. "And the difficulty is that there might not be anyone to hold accountable."

In the near future, however, the most likely use of AI in warfare will be in tactics and analysis. "AI can help process information better and make militaries more efficient," says Scharre. "I think militaries are going to feel compelled to turn over more and more decision-making to AI, because the military is a ruthlessly competitive environment. If there's an advantage to be gained, and your adversary takes it and you don't, you're at a huge disadvantage."

This, says Scharre, could lead to an AI arms race, akin to the one for nuclear weapons. "Some Chinese scholars have hypothesised about a singularity on the battlefield," he says. "[That's the] point when the pace of AI-driven decision-making eclipses the speed of a human's ability to understand. And humans effectively have to turn over the keys to autonomous systems to make decisions on the battlefield."

Of course, in such a scenario, it doesn't feel impossible for us to lose control of that AI – or even for it to turn against us. Hence why it's US policy that humans are always in the loop regarding any decision to use nuclear weapons. "But we haven't seen anything similar from countries like Russia and China," says Scharre. "So, it's an area where there's valid concern."

If the worst was to happen, and an AI did declare war, Scharre is not optimistic about our chances.

"I mean, could chimpanzees win a war against humans?" he says, laughing. "Top chess-playing AIs aren't just as good as grandmasters; the top grandmasters can't remotely compete with them. And that happened pretty quickly. It's only five years ago that that wasn't the case.

"We're building increasingly powerful AI systems that we don't understand and can't control, and are deploying them in the real world. I think if we're actually able to build machines that are smarter than us, then we'll have a lot of problems." **SF**

VERDICT

So, a warmongering AI almost certainly could outfight humans. Yay, the movie science matches real-life science for once! Oh. Wait there...

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: JOE WALDRON

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